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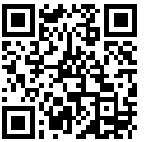

Submarine vessels

William Erskine Dommett

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SUBMARINE VESSELS

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SUBMARINE VESSELS

INCLUDING

MINES, TORPEDOES, GUNS, STEERING, PROPELLING, & NAVIGATING APPARATUS

AND WITH NOTES ON

SUBMARINE OFFENSIVE AND DEFENSIVE TACTICS, & EXPLOITS IN THE PRESENT WAR

BY

W. E. DOMMETT

ADMIRALTY PRIZEMAN; MEMBER, AERONAUTICAL SOCIETY, GREAT BRITAIN
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MEMBER, INSTITUTION MARINE ENGINEERS

AUTHOR OF
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PREFACE

AT the suggestion of the publishers, the notes on submarines made from time to time by the author have been collected together for publication. In complying with their request, an endeavour has been made to present the subject in such a manner that it shall be understood by, and together with the plates be of interest to, the general reader, and at the same time contain sufficient technical matter to be of value to a reader having some technical knowledge.

The author desires to express his very best thanks to Mr. A. B. Chalkley—the editor of *The Motor Boat*, and an acknowledged authority on Diesel engines—for the original photograph for Plate XI., and permission to use same; also to Mr. S. C. Batstone for permission to reproduce Figs. 8, 9, 10, from his "Treatise on Electric-Light Fitting." The plates have been prepared from photographs supplied by Mr. Stephen Cribb, of Southsea, the well-known naval photographer.

W. E. DOMMETT.

SURBITON,
February, 1915.

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SUBMARINE VESSELS

CHAPTER I

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"SUBMARINES, TORPEDOES & MINES."
By W. E. DOMMETT.

By order of the Admiralty some of the plates have been taken out from this book. These plates will be supplied on application at the conclusion of the War.

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SUBMARINE VESSELS

CHAPTER I

HISTORICAL

THE two new branches of our fighting forces, aeroplanes and submarines, came into the field of practicability much about the same time, of the two the latter being somewhat older and more established. Nevertheless, the air machines have become better known than the under-water machines, and for a number of reasons. In the first place, air machines have been brought to the notice of the general public through the establishment of cross-country flights and local centres of flying races, whereas the public had to seek out the submarines by going to Spithead and like places when the fleets assembled for manœuvres or review. The enthusiasm of the sight-seeing crowds on pleasure steamers at Spithead when abreast of the submarines, however, is not one whit behind that of the crowds at aerodromes. Another reason, and also a very potent one, is that the submarine is a much more complicated machine, and involves technicalities not known even to the average engineer, let alone the general public; whereas the aeroplane is relatively simple, and the engine portion at least is fairly easily

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understood by the large number of people directly or indirectly associated with automobiles.

In tracing the earlier attempts at producing and the development of submarine vessels, it is borne in on one's mind that the ultimate successful issue resulted from the perfection of the internal combustion engine, notwithstanding the use of steam engines in some cases.

In the earliest attempts ordinary wooden boats were given a complete covering deck, and the hull was entirely encased in leather or hide which had been well greased. Propulsion was effected by oars which passed through holes, water being prevented from entering by flexible diaphragms attached to the hull and to the oars. The mast was hollow, and served as an air-supply pipe when the boat was submerged.

One inventor, Van Drebbel, in the year 1620, constructed such a boat, which was supposed to have travelled under the surface from Westminster to Greenwich; but it is hardly likely that the boat did anything more than travel just submerged, as there was no provision whereby the boat would not sink to the bottom as soon as it was completely immersed.

As early as 1653 a boat was proposed which had a cylindrical central portion and conical ends, and the inventor had strong views upon its value as a fighting machine. For offensive purposes he thought that it would be valuable for attacking under water the wooden warships of the day; and that it would be impossible for others to damage the submerged curving sides of his own vessel.

A recognition of the ability to sink and raise a boat by substituting water for air in chambers attached to

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or built in the ship was realized by Symons in 1747. A number of leather bottles were fitted opening outwardly; and when it was desired to sink the boat, strings around the necks of the bottles were untied, and the water flowed into the bottles. In order to make the boat ascend, the water was squeezed out and the strings retied around the necks of the bottles.

Not long after Symons came Day, who lost his life in a boat of his own construction with which he was experimenting at Plymouth. The great feature in this boat consisted in providing a detachable weight, the release of which should ensure the boat coming to the surface.

Much about the same time an American made a big advance by employing a screw propeller for moving the boat forward, and also a screw for lowering and raising the boat. Ballast tanks and a lead weight were also fitted. The object of the inventor was to provide means for one man to get below an enemy ship, and attach to its bottom a canister containing a charge of gunpowder with which to blow it up.

Next in order of importance one has to record the efforts of an American named Fulton, who in 1801 constructed a boat with an iron frame covered with copper plates. The boat was 21 feet long, and about 7 feet in diameter; it had a detachable keel, ballast tanks, and horizontal rudders. A spike was carried which it was intended should be driven into the bottom of an enemy vessel, and an eyeletted nail used for guiding the tow-rope of a powder magazine. For surface propulsion a sail was used; it was folded down when the vessel was submerged, and propulsion was then effected

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by a hand-operated, two-bladed screw-propeller. The boat performed to the satisfaction of the French authorities, to whom it was offered, but they eventually decided to have nothing to do with such vessels, arguing, in effect, that warfare on these lines was " immoral," and in a sense " not playing the game."

After a period of some sixty years, bringing us to the year 1864, a renewal of interest in submarines occurred. It arose out of the necessity of the weaker Southern American States raising the blockade put upon their ports by the naval forces of the Northern States. A number of iron-plated hulls were then designed with a steam-power plant on board, and ballast tanks were used so that the vessel could take an " awash " position in which only the funnel was visible above the surface. For fighting, a case containing an explosive was carried from a projecting rod outside the hull of the vessel, fuses being provided which exploded the charge when the case came up against an enemy ship. In some cases horizontal rudders were additionally used for maintaining the trim.

It is impossible to estimate the real value of these submarines, but there is little doubt that, despite the numerous failures, the Northern forces did not feel any the more comfortable for their presence.

It has been possible to deal with the early history of submarines without any preliminary definitions, but it is now necessary to a proper description of the more modern vessels that some definition of the terms employed should be given. So far the vessels described have been either of the kind which runs awash, and when desired is wholly submerged ; or of the type

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which is mainly a surface vessel, but is able to be immersed to an awash or submerged condition. Such vessels have been indifferently known as "submarines" or "submersible vessels"; but latterly the tendency seems to be to class them all as "submarines."

The term "submersible vessels" should, however, be reserved for those which, whilst mainly surface vessels, can be brought to an awash or submerged condition for the purpose of fighting or hiding. A diagram (Fig. 5) drawn for illustrating another point shows a vessel in the three states: (*a*) Floating freely on the surface; (*b*) in the awash condition; and (*c*) wholly submerged. Writers of naval technics or literature have not yet settled upon any definite line of demarcation for the two classes. The word "submarine" will be used in this work as a designation for the types remaining for description. But it must be remembered that rumours are existing of proposals for constructing in the near future larger boats than are now used, which will very clearly come under the other type—that is, will be "submersible vessels."

From 1878 to 1887 Garrett, at first alone and later in conjunction with Nordenfelt, constructed boats of a shape tapering towards the bow and stern in plan view, embodying features already described in connexion with earlier boats. These features were the subject of much thought and research, and this coupled with the more advanced state of our scientific knowledge at the time gave a considerable measure of success. The inventors were thus able to produce a design of such a nature that the boats constructed from their plans performed better than any previous

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machine. Automatic controls supplemented by hand controls gave fairly good results. Steam plant of an ordinary kind was used for surface navigation, a speed of 9 knots being obtained. For under-water propulsion sufficient energy was obtained from water in which the latent heat of steam had been stored to give a speed of 4 knots, the supply holding good for three hours. A torpedo and gun were carried.

The boats all exhibited a tendency to depart from an even trim, giving the crew a very miserable time, and rendering it almost impossible to do any effective work with the gun or torpedo.

It is on record that other Englishmen also about this time were working on the submarine problem, and we find that hulls were built which were roughly of circular section tapering toward both ends; that the hulls were divided into compartments; that electric accumulators driving electric motors were in requisition for propulsion; and that air stored under pressure was utilized for supplying the crew with additional air as required when submerged, and for forcing water out of the ballast tanks.

These boats did not give such advanced results as to claim any attention from the British Government, which remained content to watch the efforts of these private individuals and the work of foreign Governments.

During the period 1875-1900 other nations were giving attention to the development of submarines and submersibles. France in particular used its characteristic engineering genius in this direction. The record of their doings might well excite our admiration. Their

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patience in working out details, in deducing the correct lines on which to develop from an investigation of their successes and failures, and, moreover, the readiness with which the necessary money and financial assistance was forthcoming—all these are lasting monuments to the French nation. As in a previous instance where a people found itself at a disadvantage under the existing conditions of and state of their preparations for naval warfare, so with the French. They could not hope to compete with certain other nations in big ships, and they argued therefore that their salvation from an invasion by sea was in submarines.

Contemporaneously in the United States of America a good deal of work was being done by Mr. Simon Lake and Mr. Holland. Both these inventors prepared plans for a boat which should come up to the requirements of the United States Navy as set out by the Bureau of Ordnance in 1893. These requirements were as follows, and rated in importance in the order of setting out:

1. Safety.
2. Ease and certainty of action when submerged.
3. Good surface speed.
4. Good submerged speed.
5. Radius of action.
6. Offensive properties.
7. Stability.
8. Visibility of enemy object.

Rightly enough, and in the same way as our own Government has since been forced to act in similar circumstances, it was left to the designers to make any

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modifications within reasonable limits they, with their experience, might wish to make.

Meanwhile the British Government simply looked on. No doubt much money was saved, and as long as a war did not occur with either of the nations who had advanced so much, we were safe. But was it really worth the risk ?

We now come to the modern submarines, the era of which can be said to have started at the year 1900.

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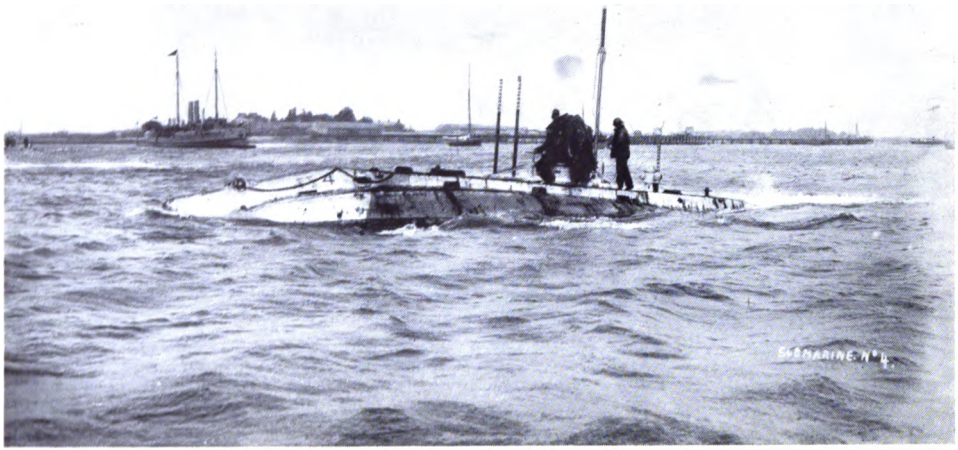

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THE A1 PROCEEDING TO SEA

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CHAPTER II

BRITISH NAVAL SUBMARINES

It was not until 1901 that the British naval authorities decided to watch and study the submarine movement in a more effective manner than that hitherto adopted by building some of these vessels for themselves, and so giving our officers an opportunity of testing their capabilities at first hand. It is quite clear that this new attitude was taken at the time because the development of the internal combustion engine had reached a stage where its value and possibilities for submarine work were apparent. Our Government wanted "speed" and more "speed" from any boats they built, and in this respect without doubt were acting on the right lines. About the same time, too, the results obtained from boats made and run in America and France had really become settled, and the deductions made from their performances of definite value.

The Admiralty started by ordering five Holland boats, the United States inventor arranging with the firm of Vickers, Sons, and Maxim (now Vickers, Ltd.) for their construction at Barrow. The first boat was entirely on the American specification, whereas in the construction of each successive boat improvements

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were embodied which were the direct result of the work done with the earlier boats.

The first boat was 64 feet long, 12 feet beam, and had a submerged displacement of 120 tons. The surface speed was 9 knots and submerged speed 7 knots, which were obtained from an internal combustion engine of 190 horse-power and an electric motor of 70 horse-power respectively. In shape the boat was cigar-like, each section being circular, the maximum size being situated slightly forward of the geometrical centre of the boat, and the " stem " somewhat blunt. Although probably not the subject of previous investigation at the time of its adoption, it is noteworthy that this form should later have been found experimentally to give the least resistance to forward motion for a given maximum cross-section. It has been a popular notion that in order to cleave its way through water or air with the least resistance, a body should be pointed or sharp at the front. The experiments which disprove this notion have been independently conducted at the chief marine and aeronautical laboratories in various countries, the several results obtained showing a marked agreement on this point. Another matter which has been experimented upon is the value of the ratio between the length divided by the diameter (or width). This ratio is known as the " fineness ratio," and must be considered as well as the form—that is, the bluntness or sharpness of the run fore and aft—when the resistance to forward motion is debated.

With this digression we return to the description of the Holland boat. Upon a framework of usual construction plates $\frac{3}{8}$ inch thick were used in building up

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the hull. The more vulnerable part, the conning-tower, was constructed with 4-inch armour-plate. Bulkheads and watertight compartments enabled the designers suitably to position the main and auxiliary ballast tanks, fuel tank, fresh-water tank, trimming tanks, compressed-air reservoirs, electric accumulators, and other necessary fittings. Beside these fittings was the steering gear, which included not only means for operating the vertical rudders usual to all ships, but also for operating the horizontal rudders or " planes " by which the vessel may be made to rise or descend, or be kept on a level course. A periscope and compass were also fitted, the former being used when navigating the vessel awash or submerged. Its fighting equipment consisted of one torpedo-tube of 18 inches diameter, and five torpedoes were carried on board.

Certain terms, such as " trimming tanks " and " periscopes," have been used which may not be familiar to the reader; but, as will be seen from the chapter headings, it is proposed to deal with all the fittings and equipment in full, and detached from the description of any one type of submarine. The reader might with advantage turn to such descriptions in cases where an expression is used which is entirely new to him.

As a result of the experience gained with the first boat of the Holland type, a larger one was designed and launched as the A 1 in the year 1902. This boat, it will no doubt be remembered, was sunk at Spithead by the *Berwick Castle* in March, 1904, whilst taking part in some manœuvres. The author, at that time working in H.M. Portsmouth Dockyard, well remem-

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bers seeing at 6.30 a.m. the placards of the local papers announcing to the dockyard and naval men the disaster, and there also remain impressions of the emotions and opinions it aroused. What speculations there were as to whether the officers and crew were still alive, and whether the salvage and raising operations would be attended with success! He is of the opinion that the suspense of the days immediately following the accident were as agonizing to the dockyard town as any within living memory. Plate II. is an illustration of the A 1.

The length of the early members of the A class was 100 feet, the beam 12 feet 8 inches, and the submerged displacement 180 tons. The internal-combustion engines of 600 horse-power ensured a surface speed of 12 knots, whilst a submerged speed of 8 knots was attained by these boats.

The B class boat's dimensions and capabilities are as follows: Length, 135 feet; beam, 13 feet 6 inches, with a submerged displacement of 280 tons. The 850 horse-power engines give a surface speed of 13 knots, whilst the submerged speed is 9 knots. The reserve of buoyancy in this class is 8 per cent. The B 11 is shown in Plate III., in the background being the Haslar sea-wall.

The C class are but very little larger than the B class, the length being 150 feet, and the displacement 310 tons; but the installation comprises two propellers instead of one, whereby the surface and submerged speeds are 14 and 10 knots respectively. Plate IV. is a photograph of the C 34.

The D class characteristics are: Length, 150 feet;

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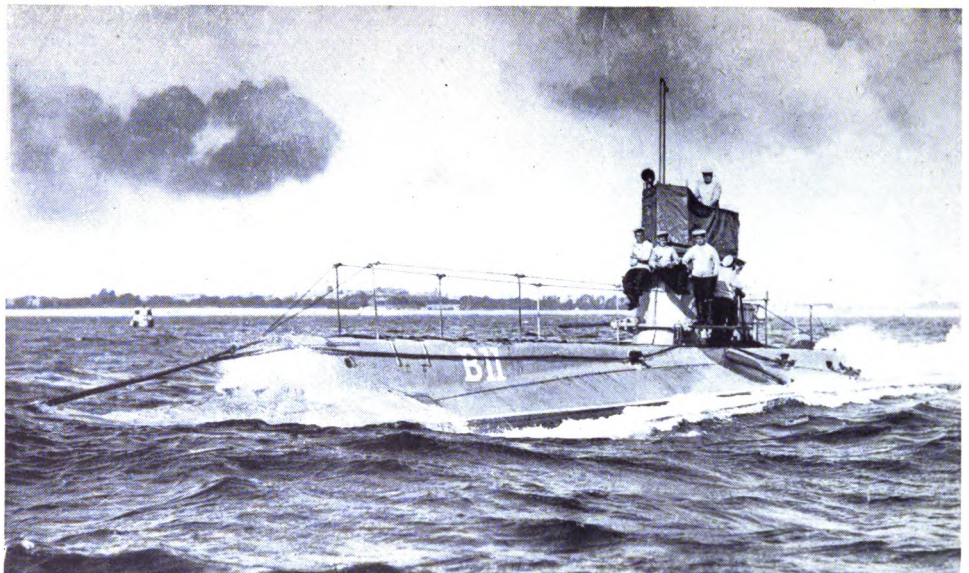

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THE B 11 RUNNING LIGHT

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beam, 15 feet; submerged displacement, 500 tons; the surface and submerged speeds are 15 and 10 knots, which is obtained from internal combustion engines and electromotors with horse-powers of 1,200 and 550 respectively. The reserve of buoyancy is 12 per cent. The later boats carry 15 tons of fuel, with a radius of action of 1,700 miles, and have a displacement of 600 tons. The equipment includes a wireless mast, two periscopes, two bow and one stern torpedo-tubes, and six 18-inch torpedoes are carried. The officers and crew number twenty-one. The D 1 with wireless mast in place is shown in Plate V.

For the latest boats, belonging to the E class, the following data is approximately accurate: Length, 178 feet; beam, 23 feet; submerged displacement, 800 tons. The propelling plant comprises two heavy-oil engines, each of 900 brake horse-power, the total of 1,800 horse-power producing a surface speed of 17 knots. The submerged speed is 11 knots, and the electric motors are of 800 horse-power. The armament comprises four torpedo-tubes, and two disappearing quick-firing 3-inch guns. The torpedoes are 21-inch, and six are carried. The bow is not unlike that of a torpedo boat destroyer, and serves as a wave-breaker when running awash. The officers and crew number twenty-five. In the matter of equipment, three periscopes are carried. The example of this class given in Plate VI. is the E 6. The frontispiece shows the bow of the E 8.

The vessels of the F type are to have a light displacement of 950 tons, and a submerged displacement of 1,200 tons, surface and submerged speeds of 20 and

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12 knots being obtained from Diesel engines of 5,000 horse-power and electro-motors of 2,000 horse-power. The armament comprises six torpedo-tubes and four quick-firing 12-pounder guns. The radius of action is 2,000 miles.

The following details of the proposed G class are given with due reserve as to accuracy: It is stated that the submerged displacement is to be 1,500 tons. Also that the designed speeds are 24 and 18 knots for surface and submerged running, the engines being of 6,500 and 2,400 horse-power respectively; the radius of action under the two forms of propulsion being 2,800 and 900 nautical miles respectively. The length is probably about 225 feet. The armament will be two 4-inch guns and eight torpedo-tubes; whilst the wireless will provide for sending and receiving telegraphic and telephonic messages. The complement suggested is three executive officers, two engineer officers, one surgeon, and forty-six men.

Although Vickers, Ltd., were at one time the only constructors of submarines for the Navy, yet latterly the Admiralty have built a few at Chatham Dockyard, and advantage is now being taken of an expansion of the programme for giving submarine work to other naval shipbuilding firms.

Contemporaneously with the F and G classes, Vickers Ltd. are building a series of submarines of which the first is to be named the *Nautilus*. The *Motor-Boat*, which has followed submarine work very closely, suggests that it can reasonably be dubbed a "supersubmarine." To Messrs. Scotts, of Greenock, have been given orders for an S class, the designs of

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which are on the lines of the Laurenti type used in the Italian Navy; and Messrs. Armstrong, Whitworth, and Company have been entrusted with the W class, which is of the Laubeuf type used in the French Navy.

The policy of expanding both the number of types and the number of building firms is splendid so long as reasonable limits are observed.

An estimation of the policy which it is intended to

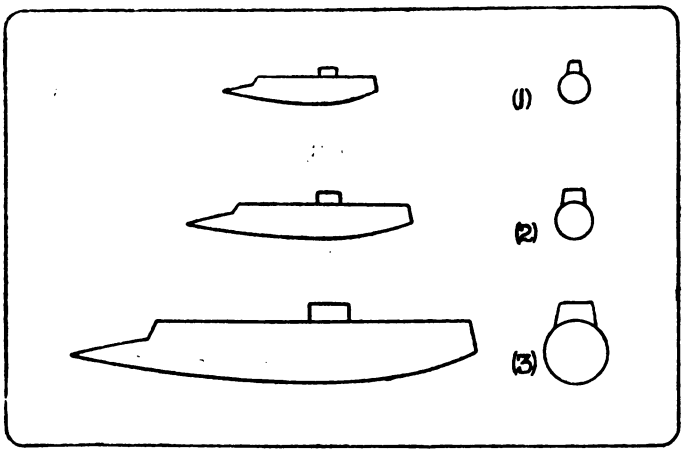

FIG. 1.

pursue can be obtained from an investigation into the dimensions of the Laubeuf. These vessels are of 600 tons, with surface and submerged speeds of 12 and 9 knots, and with heavy oil engines of 700 horse-power. The armament comprises two bow and one stern tube for 18-inch torpedoes. This class of submarine is obviously to be used for coast defence work, leaving to the supersubmarine cruises of 3,000 odd

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miles. The early Laubeufs were the first submarines to be made with twin hulls, a feature which is now general. The reserve of buoyancy is very high, reaching the value of 30 per cent.

Some idea of the advances made during the period 1901-1914 may be gathered from the diagrams in

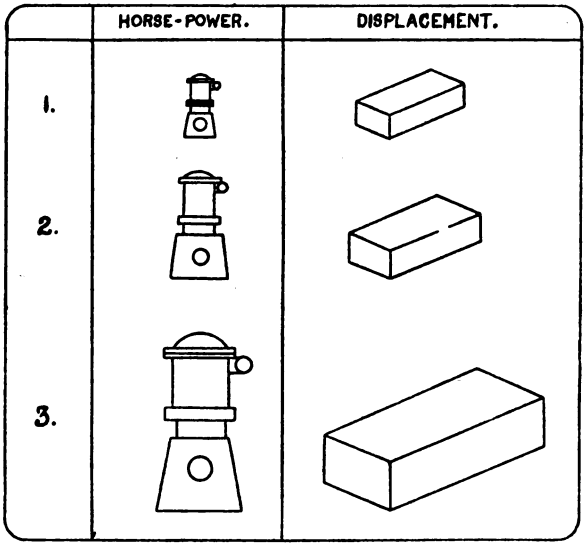

FIG. 2.

Figs. 1, 2, and 3. For the sake of comparison in respect of the dimensions these have been drawn to scale in Fig. 1 for three of the types. Distinguishing numerals (1), (2), and (3) are used, wherein (1) stands for the first Holland boat built at Vickers; (2) for the A class; (3) for the E class. Other graphical comparisons showing the brake horse-power and displacement

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are given in Fig. 2 for the same three classes of boats enumerated above. In Fig. 3 the upper curve represents the surface speeds in knots, and the lower curve the submerged speeds for the early Hollands (H), and the A, B, C, D, E, and F classes.

The broad characteristics of the various classes and types built and building for the British Navy have now been given. It will be noticed that the plates show

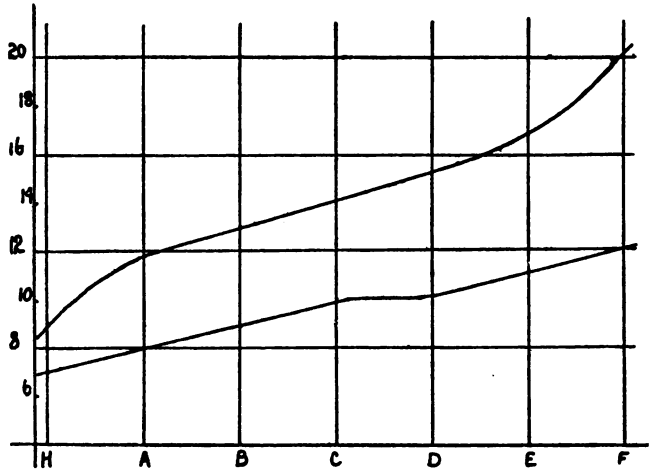

FIG. 3.

boats with numbers painted thereon; for example, the A 1 is numbered 4, the C 34 is numbered 64, and the D 1, 71. The continuity of numbering, which is used in addition to class numbering, begins with the first Holland boat.

In order that one may gain some idea of the general arrangement, a complete sectional drawing is attached.

In the large folder plate of Fig. 4 are presented the

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main features of a modern submarine assembled in their correct places and true to scale.

The walls are double, the space between these walls being in communication with the outside water, so as to prevent the outer wall, which is generally constructed of light material, from being crushed by the increased pressure on submergence.

The vessel illustrated in Fig. 4 possesses a comparatively light structure arranged in this manner; and also has comparatively light surface draught with adequate stability, both on the surface and submerged, and has ample head room throughout the interior portions occupied by the crew in handling the vessel.

The inner hull is arranged in the midship section of the boat, with its axis arranged above that of the outer hull.

The boat is equipped with forward and after trimming tanks, an auxiliary ballast tank, and preferably an adjusting tank.

The trimming tanks are employed for the purpose of bringing the vessel to an even keel before submergence, and in practice are seldom or never completely filled, so that they must be capable of withstanding the pressure of deep submergence. The auxiliary ballast tank is employed for the purpose of overcoming such portion of the reserve buoyancy of the vessel as may be desired after the main ballast tanks are completely filled and the vessel is properly trimmed fore and aft by the trimming tanks. The trimming tanks are made a part of the strong inner hull, and in order to have the maximum effect for their intended purpose, are located at the extreme forward and aft portions

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thereof. The auxiliary ballast tank is likewise made a part of the inner hull, and is so constructed and located, whether made of one or a number of compartments, that the centre of gravity of its contents is in or near a vertical line passing through the centre of gravity of the vessel submerged, so that the amount of water in it has little or no influence on the fore and after trim of the vessel.

The rear wall of the forward main ballast tank is the bulkhead, 2, which forms the front wall of the inner hull, 3. Torpedo-tubes, 6, extend through bulkhead, 2, and two other bulkheads, 7. The space between the bulkheads, 7, constitutes the forward trimming tank, 8, and the space between forward bulkhead, 7, and bulkhead, 2, constitutes the torpedo compensating tank.

The forward part of the strong hull, 3, is slightly elliptical, with its major axis vertical, and is well adapted for exterior pressure-resisting construction. From this form it gradually merges into a true circle, and is in greater part cylindrical, but embraces at its lower portion a boxlike rectangular structure, 5, which forms part of the pressure-resisting hull, and accommodates the storage battery equipment, 9, the adjusting tank, 10, and the auxiliary ballast tank, 11, at a low and convenient level.

The rear wall of this central double-hulled section of the boat is a bulkhead, 12, and from here back to the bulkhead, 13, the single-hull construction is again used, and as its cross-section is substantially an ellipse, with its major axis horizontal, the hull is braced against exterior pressure by carrying up the engine frames and by vertical stanchions.

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The portion of the strong hull just forward of the bulkhead is divided off by a second complete transverse bulkhead, to form the after-trimming tank, 14.

From bulkhead, 13, to the stern of the vessel the structure supports the twin propellers and shafting.

The space between the midship section of inner hull, 3, and the outer hull, 4, is used as main ballast tankage, and is divided as desired. For the purpose of giving light surface draught this portion of the hull is, as shown, spread out broadly toward the bottom, which is nearly flat, and is of small height as compared with its width. This arrangement is well adapted to the combination of light surface draft with a large submerged stability and a good surface stability.

A superstructure enclosing space, 15, is built throughout the entire length of the boat, and serves to reinforce all of the before-mentioned sections, as well as to form a deck for the vessel. This superstructure is ordinarily non-watertight, and is provided with vents, and with scupper-holes where it joins the hull, to render it self-bailing and self-filling.

Closures for sea inlets and air and pump connections are provided for all of the non-pressure-resisting spaces which are intended for use as ballast tanks—the ballast tank space in the middle section, the bow and stern tanks, 1 and 14, and the superstructure space if it is made watertight—and they can be flooded or exhausted either singly or in combination.

In the forward part of the ship and on the deck are mooring cleats, whilst passing through the forward tank, 1, is a tube through which passes the mooring cable, and in the lower part of which is housed the

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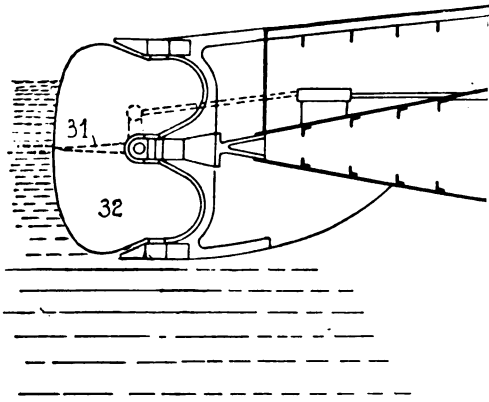

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anchor. The cable is operated by an electric motor in the compartment, 34. Rods operated by power cylinders also pass from this compartment through the bulkheads, 7, 2, for opening and closing the bow caps, 27, 28, of the torpedo launching tubes, 6. Beneath the reserve torpedoes are the air cylinders, which are carried in the space, 35. In the space below the deck, 15, is housed the disappearing gun or guns.

In the centre of the ship are steering-wheels, 16, 17, for steering when on the surface and when submerged. These wheels set in motion the motor on the steering connexions, 23, which pass to the horizontal rudders, 31, and vertical rudders, 32. Clearly shown in the drawing are the companion ladders, 21, 22, periscopes, 24, 25, ventilators, 18, 19, and ventilating pump, 20. In the central compartment are also placed the switchboard, with all electrical controls and switches, the gas-vents for the accumulators, and the gyro-compass. Before submergence the temporary railings, 26, are dismantled, all hatches closed, the ventilator valves closed, and the internal combustion engine stopped.

The after-main compartment is filled with the two engines, 29, the electro-motors, 30, air-pump, 33, and other machinery.

The photographs or plates of submarines provided should be studied in conjunction with the foregoing description, when no difficulty should be experienced in getting a general impression of the design.

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CHAPTER III

SUBMARINE TACTICS—DEFENCE AGAINST SUBMARINES—EXPLOITS IN THE PRESENT WAR.

UNTIL the present war the submarine was an untried unit of the Navy. In the Spanish-American War some very small incidents occurred in which the crude submarines of that day were involved, but these could not be used in any way as a basis for theorizing upon. During the ten years that these vessels have been attached to the Service, the main work of the personnel consisted in acquiring the art of navigating the boats, and but little work on the military side has been put in. It is true that the flotillas have taken part in manœuvres, but very little was accomplished toward establishing the correct relationship of this type of craft to the others. What is really happening is that the commanders are now tumbling on different possibilities for their boats every day, and duties occur which were not thought of before, but which it is now found they can suitably perform.

For a time submarines were regarded as *coastal defence* vessels only, and rightly so in the days when the radius of action was restricted. The naval forces stationed at the main dockyards were given the duties of guarding certain lengths of coast, and the flotillas

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stationed there were then split up, and operated from suitable bases, which were established at other smaller and non-naval ports. The function of the submarine was to co-operate with the observation mines, boom defences, and other defences of the main ports against an attack from enemy surface ships.

As the vessels got larger, and could act in heavier seas and over greater distances, so they took their places with the fleets. The invisibility of the submarine is its greatest asset as a fighting member; next to that would come its property of being able to attack with the most destructive weapon a ship can carry—that is, with the torpedo; then a feature in its favour is that it is distinctly a difficult object to be attacked, even when seen. The feature which is against them, however, is their inferior speed, so that, unless towed by torpedo-boat destroyers, there is but little chance of keeping up with the main fleet. Upon the outbreak of war, the advantages of the submarine were put to a use which did not demand co-operation with the main fleet, and so left everything in the submarine's favour. Theirs was the duty of reconnoitring the home waters of the German Fleet with a view to finding out all that could be learnt of the positions of the anchorages, the dispositions of the boats, and their activity or otherwise. Only submarines could do this without attracting attention, it being essentially a daylight job. Seaplanes could have been employed, but would have been seen if they had descended low enough to make the observations.

The adventure into the domain of the enemy on a reconnaisance was also accompanied by individual

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or *independent offensive action.* The E 9, commanded by Lieutenant-Commander Max K. Horton, penetrated into the Bight of Heligoland, and succeeded in torpedoing and sinking the small cruiser *Hela.* This was on September 13. Of the two torpedoes discharged, one hit the cruiser at the bow, and the other amidships. Later, on October 6, the E 9 was again successful, and sank the torpedo-boat destroyer S 126 by a torpedo. The official communication of the act to the Admiralty by the Commodore describes this success as resulting from patience and skilful zeal. It stated that the tactics pursued by the torpedo boats, coupled with their shallow draft, make them very difficult to attack successfully with a torpedo.

In both these instances it is certain that the first object was to obtain information, and that the fighting was incidental. Advantage was taken of the opportunity which presented itself.

Independent offensive action may be practised by design, an instance of which would be the glorious feat of the B 11, which penetrated the Dardenelles and torpedoed the old Turkish warship *Messudieh,* acting as guard-ship. Beside running the gauntlet of an extensive mine-field, there was the risk of getting into such shallows that the defensive action of sinking the vessel could not be performed. It was therefore subjected to the serious risk of gun-fire. As it was, the boat was submerged for nine hours, resting on the bottom in a manner similar to the A 12, which is shown aground in Plate XV., during which time the B 11 (Plate III.) was brought out of the range of the Turkish guns. It is no exaggeration to say that the

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feat is one of the finest the world has known. Small wonder that the commander, Lieutenant Holbrook, has been awarded the V.C., and the second in command given the D.S.O.

Although only a hindrance to any fleet advancing to an attack, yet, if fast scouting destroyers can give warning in time, it is possible for the submarines to *go into action with the main fleet*, and to take up a station toward the rear of the opponents, and in a position along which the enemy boats may be driven. At the proper moment the submarine can then launch its torpedoes. The case under consideration is that in which the attacking fleet has a superiority in guns and speed.

In the case when guns only are superior, and there is nothing to choose between, or the speed is inferior to the enemy's, then it is possible for the defending side to choose its own line of escape, in which case the enemy submarine could have been steadily brought up to wait for the pursuers. Such a case occurred recently when Admiral Sir David Beatty, with the Battle Cruiser Squadron, had to give up following a German Fleet owing to the possibility of the German submarines being near.

A case which ought to need no consideration, as it is nothing more than an easily-seen-through ruse, is that in which an enemy, superior in guns and speed, is able, by feigning inferiority, to draw the opponent to a predetermined place with a view to avoiding gun-fire, but alternatively to use the submarines for sinking the enemy.

Whether it be a case of independent action or joint

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action with the fleet, one very successful attacking ruse consists in sheltering the boat behind a fishing-smack, trawler, or like vessel flying a neutral flag.

It is difficult to generalize with any degree of accuracy on a subject which is growing and expanding every day, and one has to be even more careful in making deductions from a particular instance. The merit of the work of the Service so far has been that not one of the operations would appear to have been planned as a result of generalizations or particularizations. Each little excursion has seemingly been self-contained, hence the difficulty in trying to examine future policy of a Grand Fleet action which includes as combatants all three arms—air-craft, surface vessels, and submarines—in the light of, say, the Cuxhaven engagement.

As far as can be gathered from the reports, our Light Cruiser Squadron, accompanied by submarines and carrying seaplanes, proceeded on Christmas morning to the Heligoland Bight. The seven seaplanes were sent off to drop bombs on Cuxhaven shipping-yards, and to make observations over the Kiel Canal. When Germans observed them, they came out with Zeppelins, air-craft, submarines, and destroyers. We sustained no losses, and as the seaplanes returned, some were picked up by the cruisers, whilst others were destroyed and their pilots and observers taken on board by submarines, *according to previous arrangement.* Undeniably this new duty is an excellent one, and was no doubt suggested by the incident in which the crew of a disabled Taube seaplane were taken prisoners by one of our submarines, and the machine destroyed.

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Blockading comes also within the sphere of duties, and falls somewhat into the same category as the reconnoitring just described as far as it concerns the enemy's fighting vessels. We are now hearing, however, of an extended use, whereby a more complete blockade may be attempted, wherein the submarine uses its gun to stop and threaten a merchant vessel for examination of the ship's papers. Should the papers prove the boat to be neutral or friendly, and the cargo not contraband, the boat is released. If otherwise—well, the possible action depends apparently on the whim of the officer commanding the submarine in the case of a German submarine, and depends upon properly constituted international law in the case of a submarine belonging to the Allies.

Up to this point mention has been made of the attacking properties, and one other matter remains to be dealt with on this head—viz., the behaviour of a submarine when attacking—and then consideration will be taken of the defensive methods employed against submarine attack.

For a torpedo to be effective, it must hit as nearly amidships as possible, when larger sections of the vessel will be disrupted. This implies that the submarine shall be in as favourable a position as it can possibly get. It must get up close without being seen, and must be able to discharge the torpedo as nearly as possible at right angles to the direction of the ship. The difficulties demand that the boat be submerged, and if direct sighting must be done, then a porpoise-like series of rises and dives should be executed, so that the periscope is above water only long enough for

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an observation to be made, and no longer. If direct sighting is not desirable or necessary, then the boat should approach submerged by dead reckoning.

Defensive measures for boats in harbour include observation and specially laid and charted contact mines, and for inner harbours comprise boom defences, such as chains, and spars, and mines spread across the harbour mouth.

That these are not always effective has been already proved by the B 11, for the commander skilfully navigated his boat through several mine-fields in the narrow waters and swirling currents of the Dardenelles. In the more open waters, submarines are continually passing through mine-fields, and but relatively few mishaps have taken place. The E 6 was fortunate enough to escape without injury even after a mine-mooring became entangled in the horizontal rudder or hydroplane and its guard. After a period of nerve-racking work by Lieutenant F. A. P. Williams-Freeman and Able-Seaman E. R. Cremer, they were successful in freeing the mine and being in a position to go ahead again. Additional protection to anchored boats is provided by torpedo-nets, when fitted. These consist of closely woven steel net suspended from booms pivoted to the side of the vessel so fitted. The booms are about 25 feet long, and the netting goes to about 15 feet or more below the water-line. When not in use, the nets are folded along the sides, and the booms swing in to rest against the sides. This protective device has been a matter for much argument between different schools of thought.

The speed of a battleship with torpedo-nets out is

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not more than 6 knots, and this system of defence against torpedo attack is therefore not of outstanding merit.

For commanders of boats who fear a day attack, but have no knowledge of the whereabouts of the enemy, the wisest plan to adopt consists in going at full speed, and occasionally and irregularly making deviations from the course that would otherwise be taken. The submarine cannot then attack by dead reckoning, and must either come up to make observations, or trust to luck more than reckoning for being in the best place for attack when the boats are abreast.

The sudden appearance of a submarine very near a ship gives to the commander certain options. On the one hand, he can turn tail, presenting little target, and run out of range if fast enough. If not fast enough to get away, and if there is a gun of any sort on board, fire can be opened on the submarine. Following on the assumption that the submarine is the faster, it will presumably be " light " or " awash," and will have to submerge. What with the delay of the submarine occasioned by the process of diving and its small underwater speed, there is a chance of getting away. If the surface boat is not fast enough to get away, and there is no gun aboard, in any case an end-on approach provides but a small target, and there is a sporting chance of ramming the submarine. If the ramming is successful, and the plates are stove in or forced, so as to let in water, evidence thereof is immediately forthcoming in the presence at the surface of gas-bubbles and oils.

For guarding against night attack at sea, whether

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from torpedo-boats or submarines, a high speed and no lights on board is the safest method of procedure.

The larger warships should always be screened by a number of swift torpedo-boats. They can prevent submarines from getting the range of a big boat; they can intercept, if need be, an oncoming torpedo; they can fire at or run down any submarine which attempts to come up for observation. The first and last items have been performed quite a few times, notably in the first Heligoland Bight engagement, and in the case of the *Mersey*, *Humber*, and other ships anchored off the coast of Flanders, and employed in bombarding the German lines and the port of Zeebrugge.

An instance of the successful entrance of a submarine flotilla into a harbour containing warships occurred early in the war at one of our Northern ports. The guardship was passed before the flotilla was noticed. The torpedo-boat destroyers were called to harass them as much as possible; meanwhile the capital ships got up steam, weighed anchor, and slipped away. The incident was related to the author with great gusto by one of the crew concerned, who likened the whole business to a rat-hunt. Every time a submarine came up to take its bearings in the bay, after it went a destroyer, until the whole lot were headed off from the escaping fleet. No torpedo-nets being out, the large vessels were able to get away.

Co-operation with aeroplanes is advisable as a means of detecting the presence of submarines. It is known that the higher one proceeds above the surface of water, the deeper one can see beneath the surface. The detection of objects such as submarines in the

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water from air-craft is thus possible, with the prospect that information may be given with a fair margin of time to battleships, when such submarine is an opposition one. The water must be fairly clear and smooth, and also the bottom must be of such a character that it can reflect light. Concerted action between seaplanes and submarines is possible for both offensive action as well as defensive action.

After a supposed attack on Dover Harbour, a number of destroyers went out hunting in couples for the submarines. Strong cables were slung between the destroyers, to which bombs and grapnels were attached near the centre, so as to drop down into the water. The boats then cruised up and down at a fair speed with the object of coming across any submarines which might be lying submerged and waiting to get away unseen. Exactly what would happen if a submarine were caught by the cable is not quite definite. It is thought that the manœuvre was successful in finishing off one boat, for oil and gas was coming up at one place in noticeable quantities.

Number of Submarines in Various Navies.—At the beginning of the year 1915, the number of submarines in commission, as far as can be ascertained, were 95 British, 33 German, 95 French, 40 Russian, 20 Japanese, and 5 Austrian.

About twelve of the British boats are abroad, the remainder being in home waters. It is stated that we can complete twenty-five new boats during the year, *including* the eight building at Vickers's yard in Canada. Leaving out losses, the total at the end of the year would be 120.

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Some eleven or so of the German boats are in the Baltic, and the remainder in the North Sea and Heligoland Bight. In the canals behind Zeebrugge rumour has it that submarines are being built from sections sent overland from Germany. It is extremely doubtful whether this is so. Prior to the war, Germany intended to lay down six each year, but the programme has no doubt been accelerated, and might as a maximum reach the neighbourhood of sixteen by the end of the year, giving a total of forty-nine. It must be remembered that Krupps and Dantzic Yard only have built submarines. In the *Motor Boat* for January 21, 1915 there is a statement to the effect that Germany has ordered forty new 900-ton submarines to be completed by the end of 1917. This paper is always very reliable with its submarine news, consequently this statement is of value as an indication of German policy.

France has her boats divided among her various naval bases, as also has Russia, whereas Japan keeps her boats in home waters, and Austria retains hers in the Adriatic. No real information can be obtained as to any revised war programme for building submarines.

Reviewing the first six months of the war, there is forced upon one this fact, one which fills us with pride and admiration, that the British naval folk are still the best in the world. In the older and more established branches they remain pre-eminent; in the newer arms of the Service, both up in the air and under water, the feats performed have thrilled the whole Empire. The courage of officers and men under all circumstances is indisputable The dash, strategy,

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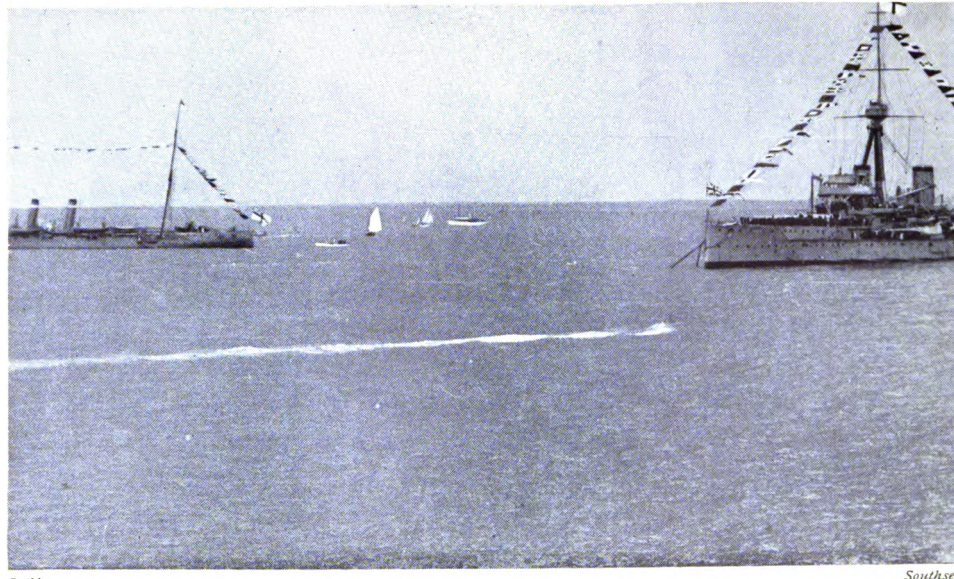

Cribb *Southsea*

THE WAKE OF THE PERISCOPE OF A SUBMERGED SUBMARINE

To face p. 32

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and tactics are worthy of their Elizabethan forefathers who swept away the Armada. And one must not forget the boats and their designers. The designers and constructors, once they had started, have improved and created new lines of development with that instinct for the best which is a factor common to all our naval products.

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CHAPTER IV

STEERING AND MANŒUVRING APPARATUS

THE submarine should be capable of navigating on the surface and beneath the surface, retaining stability under all circumstances; and its properties should be the same as those demanded by the American Government when asking designers to enter a competitive design for their consideration. The properties insisted upon were a maximum of speed, safety, offensive power, and habitability, a trustworthy means of propulsion, and a complete independence of all exterior help while in action.

The submarine or submersible has the power of sinking beneath the surface and rising at the will of its navigator, and therein is the first distinction between it and the surface boat.

Any body floating freely in water displaces a volume of water whose weight is equal to the weight of the body. This is a fundamental law of Hydrostatics. This weight is known as the Displacement. The condition of floating freely is sometimes put in another manner: the body is said to be Buoyant, the pressure of water upward being equal to the weight of such floating body. Now, if we consider a submarine in a light condition (*a*) or in an awash condition (*b*) or totally

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submerged (*c*) (Fig. 5), the Displacement when submerged is a definite amount for a given vessel, whereas the displacement, light, or awash, varies with the degree of submersion. Usually the light displacement is about 90 to 80 per cent. of the submerged displacement; and the difference (10 to 20 per cent.) is known as the "reserve of buoyancy"; in later boats the value has risen to 30 per cent.

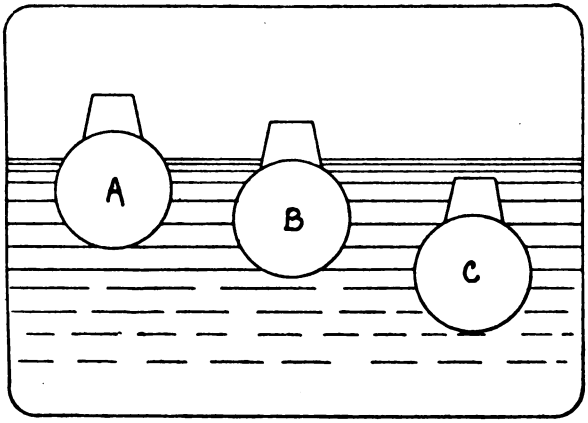

FIG. 5.

Now, the definite value of the submerged displacement denotes the limiting value in which the vessel just does not sink and just does not float up out of the water. Any diminution in the weight on board makes the boat rise until the new submersed volume displaces a weight of water equal to the new weight of the boat. The boat is then said to be possessed of positive buoyancy. In the opposite case, if the weight on board be increased, then the boat will sink, for it cannot displace any

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greater volume. In this state the boat is said to be negatively buoyant.

The law of hydrostatics involved has been very neatly demonstrated as follows: Consider a cork floating on a basin of water so that its weight is supported by the floatative power of the water. Now imagine the water to be frozen and then the cork removed—there will be a hole in the ice equal to the volume of displacement of the cork. If this hole be filled with water, and the surrounding ice be melted, we know that the added water will be supported by the same action or force as the cork was; hence we argue that the weight of the cork and the weight of the added water are equal—that is, the weight of the floating body equals that of water, having a volume equal to the displacement volume of the body.

Suppose we desire to pass from the condition (*a*) to the condition (*c*), then a downward pull must be exerted on the vessel, and its maximum amount for complete submersion must be equal to the reserve of buoyancy.

How is this pull exerted? Sometimes screw propellers on vertical axes are used. These are either situated in wells or tubes passing through the ship, or are placed at the sides. In order to sink on an even keel these must be properly placed with respect to the centre of gravity of the vessel. The difficulty experienced with this form of operation is that it is next to impossible to so time the starting, stopping and revolutions of the propeller that the boat goes down to the desired depth and stops there. It invariably produces longitudinal oscillating movements on either side of the

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Cribb *Southsea*

BOW WAVE AS SEEN FROM THE CONNING TOWER

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proper depth, which, when the vessel is under way, gives rise to an undulating path. This method is essentially one of compulsion; immediately the screws are stopped and the compulsion removed, the natural buoyancy of the vessel asserts itself and it rises. One thing, however, in its favour is that it operates whether the boat is under way or whether it is not.

This advantage also applies to the cases in which the reserve of buoyancy is overcome or destroyed by filling tanks with water, and so adding to the weight of the vessel. But here, also, it is practically impossible to get complete submersion and remain at a given depth by adding to the weight of water contained in tanks; for as soon as one gets to a state of negative buoyancy the boat goes down till it rests on the bottom. Any correction for this, by alternately emptying and filling the tanks, has the effect of producing oscillations about the desired position. Even when these corrections are effected automatically, there are still some undesirable oscillations.

In the main, the automatic correction is obtained by having a cylinder with a diaphragm at one end, which is subjected on the outside to the pressure of the water. The value of this pressure is dependent upon the depth. On the inner face of the diaphragm is a spring, and to the centre of the diaphragm is fixed a control-rod. The spring can be adjusted so that its pressure on the diaphragm will be equal to the pressure of the water at the particular depth of submergence it is desired to run. If the boat rises or falls about this depth, the water-pressure is overcome by or overcomes the spring, so that the control-rod is correspondingly

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moved outwardly or inwardly, and by its connexion with a flooding valve or air-pressure valve respectively produces a filling or emptying of the tank to restore the balance.

Some boats are fitted, however, with a similar depth regulator, but it only acts in one direction. In the strict sense it is not a depth regulator, but a preventative device which makes it certain that the boat will not go below a certain depth, unless, of course, the ship is leaking as a result of a collision or from other causes. In this case the spring acting on the diaphragm is set to balance the pressure of water at a certain depth, and as soon as the depth is reached the diaphragm moves the control-rod, and the ballast tanks are freed of water to such an extent that the boat is bound to come to the surface.

This idea was borrowed from an earlier period, which saw boats fitted with a detachable weight arranged to be operated by the crew from inside the boat whenever they wanted the boat to rise. The defect of this arrangement is too obvious to need consideration.

Three tanks at least are used on all submarines—two main ballast and trimming tanks, one forward and one aft—and these are coupled so that water can be forced from one to the other if needed. If for any reason, such as men shifting their positions, or the using up of ammunition, the balance of the boat is destroyed and the bow or stern rises, then the trimming operation is performed. In addition to this, the two tanks acting together are used for changing the boat from the light to the awash condition, and *vice versa*, by the process of filling up or emptying them of

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water. The boat is kept on an even keel during this operation. The third tank is the auxiliary ballast tank, situated centrally along the length and in the bottom of the boat, and is used for making up for small changes in the weight of stores and men on board by letting in water or emptying it.

The water is allowed to flow in past special valves known as Kingston valves, and is forced out by air under pressure.

This air is in part that compressed by the water itself when entering the tank, and in part is obtained from long steel storage cylinders, which are filled with air at 2,000 pounds pressure per square inch by an air compressor driven off the main engine. The air in the cylinders is also used for charging the air-tanks of torpedoes, for discharging torpedoes from the launching tubes, for forcing water from one trimming tank to another, and for forcing water out of the ballast tanks; and as these different operations are most economically performed with air at different pressures, each supply-pipe is fitted with a " reducing " valve, whose function it is to maintain the pressure of the air delivered to the tanks or torpedoes at a predetermined value.

Having considered how a boat can be brought to an awash condition, and also some unreliable methods of attempting to submerge it completely, it now remains to describe the modern and successful methods of submerging.

Before doing this, and in order to put clearly the principle underlying the new method, it would not be out of place to recall to mind similar phenomenon

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such as that of a boy's kite. Although heavier than air, yet it can be supported in the air if pulled quickly through it so that the air impinges on it. One must remember that the air not only pushes up on the kite surface, but also pushes, or tries to push, the kite back. The latest aeroplanes are similarly supported by planes upon which a lifting force is exerted by the air when the aeroplane is being pulled or pushed through the air by the screw propeller, and, as is generally known, they must descend whenever the propeller stops revolving. It is strange how so many parallels between aeroplanes and submarines can be found. Many attempts had also been made to lift an aeroplane by screws on vertical axes, but they were no more successful than the similar attempts to submerge a submarine by screws.

The modern method of submerging consists in using hydroplanes, or horizontal rudders, which extend out from the boat at the forward and after ends of the ship, or only at the after end. Upon the rudders being turned on their axis, an upward or downward force is exerted depending upon the angle of the rudders with the horizontal, *and* the speed of the boat. If the boat be stopped in its forward movement, then it must rise to the awash condition, whatever be the position of the rudders. The force required to operate these rudders is great, and although emergency hand-operating gear is fitted, yet they are ordinarily actuated by a small engine, only the valve of which has to be moved by the member of the crew detailed for that duty. This man, upon receipt of an order for diving or rising from the commander, moves the rudder actuating gear until

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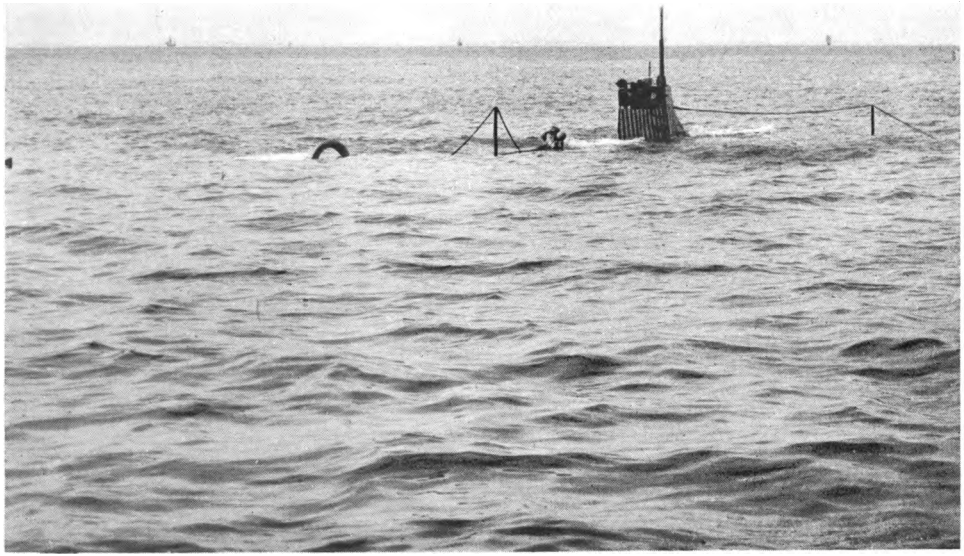

Cribb *Southsea*

A SUBMARINE DIVING FROM THE AWASH POSITION

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a gauge above the gear registers the desired depth. He is then responsible for keeping the depth, which demands continuous attention to the gauge and numberless small movements of the rudder. The position of the hydroplanes should be noted in the view of an E Class boat, which is shown on the launching stocks in Plate XIII.

When submerging is effected by the pressure of water on inclined planes, the boat leaves its even keel, and its nose goes down relatively to the stern. This operation is accurately described as "diving." The older method of sinking on an even keel ought not to be described as a diving operation.

The operation of diving is illustrated in Plate IX.; whilst the boat in Plate X. is shown coming up from a dive, the upward tilting of the stem being clearly visible.

In the latest boats arrangements have been made for carrying the bearings of the rudder stock or spindle on a sort of turn-table, so that the planes can be folded back when the boat is not submerged and does not require them. This is particularly valuable when the boat is coming alongside its parent ship or quayside, for there is some risk of breaking them when they are extended. The same argument applies for ordinary cruising, as there is always a risk of hitting floating wreckage. In addition, there is less resistance to the ship's forward movement, and in heavy weather they are less likely to be broken by the waves as the ship pitches.

In *Engineering* for November 17, 1911, the diving operations of a Holland boat were described, and

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photographs of the boat at different stages of diving can be seen at the South Kensington Museum. The Museum, which is open until 9 p.m. on Mondays, Thursdays, and Saturdays, and until 6 p.m. on other days, including Sundays, is well worthy of a visit from those interested in naval matters.

When preparing for a dive, the Kingston valves and air-pressure valves are tried, to see that they are in working order; meanwhile the deck is cleared of stanchions, and the wireless mast is turned down out of the way. All hatches are closed and water admitted to the tanks until the deck, which is just below the base of the conning-tower, is at the level of the water. It is absolutely necessary to close all hatches before letting the water into the ballast tanks as has been demonstrated by accidents which have occurred when the procedure has been omitted. The value of the submergence depends upon the rate at which the vessel can be submerged; the quicker it can be done, the better, especially if an enemy ship is in sight. Realizing this, designers of boats have, by fitting large flooding-pipes, endeavoured to get the water into the tanks as quickly as possible, and, consequently, the boat gets a rapid downward motion, the momentum of which carries it beyond the awash condition. Should this carry the boat sufficiently low, water would pour into the open hatches and drown the occupants, besides sending the vessel to depths at which it may be beyond salvage. If the filling process is done steadily, the boat will gradually go down to the awash condition, and remain stationary as soon as the Kingstons are shut.

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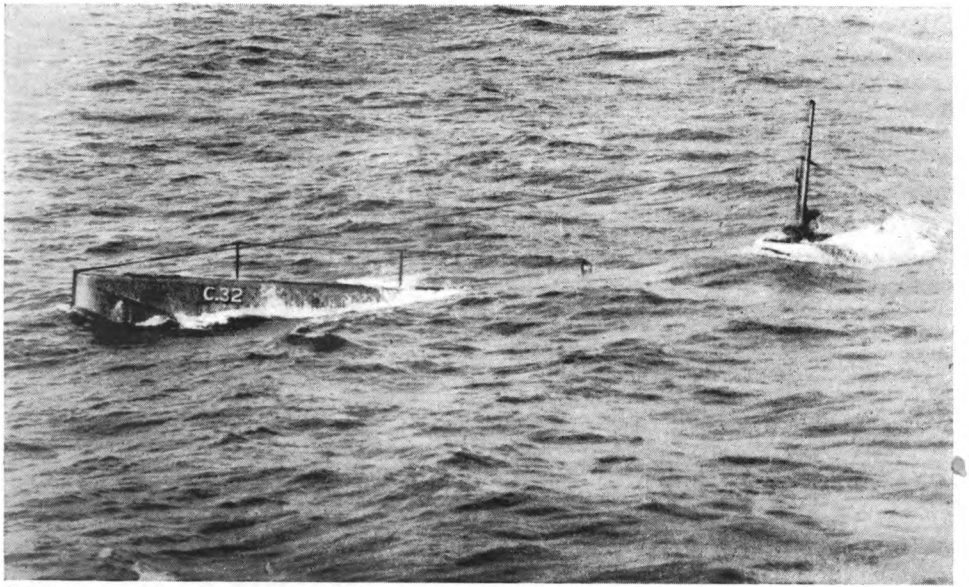

Cribb *Southsea*

THE C 32 RISING FROM THE SUBMERGED POSITION

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The order is then given to put the horizontal rudders over ½ degree, the boat proceeding at five knots, until the dive brings the base of the conning-tower awash. At this stage the helm is increased to 1¼ degrees, and remains so until half the conning-tower is in the water. It is then brought to 2 degrees, until three-quarters of the conning-tower is immersed, and then diminished to 1¼ degrees again, until all the conning-tower is submerged. By the time the dive is completed—that is, when about half the periscope is showing—the boat will be practically on an even keel, with the horizontal rudders at a small but sufficient angle to maintain the boat at this depth.

The time for this dive was five minutes, of which clearing the deck and getting to the awash condition probably occupied three minutes, leaving about two minutes for submerging by the rudders. This time has been successively reduced with each new type brought out.

For steering a course, vertical rudders of usual warship pattern are used, which are operated by rods passing from the outside to the inside of the boat through stuffing-boxes. A hand steering-wheel with chains is coupled to the rods, and in later boats a small power steering-engine is fitted.

Mention has been made of longitudinal oscillations. In addition, boats have a tendency to lateral oscillation—that is, to roll from side to side—but these are not of very great magnitude. Two bilge keels, or fins, can cope with this, more especially in boats with the high cut-water and prolonged deck, as there is then plenty of " side area " to act as a damper to the rolling.

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Another form of oscillation which is experienced is that to which the term "pumping" is applied. In comparatively shallow waters, and if a heavy sea is running, it has been found that a boat will rise and fall under the action of the swell. The motion is a slow one, but when the vertical movement amounts to as much as 30 feet, as it is said to have done with one boat when crossing from Heligoland to Harwich early in the war, one can believe that the comfort of the crew was not enhanced. Nothing has been done to deal with this, and it is doubtful whether an endeavour to mitigate the defect is worth while, any more than it is for marine architects to try and meet all the exceptional circumstances which have from time to time operated to the damage and destruction of surface vessels.

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CHAPTER V

PROPELLING PLANT

THE problem in connexion with the propulsion of a submersible boat is complicated by the fact that the steam and internal combustion engines used in surface navigation cannot be used when a boat is submerged unless complicated methods are adopted for this purpose. From the following description of the two forms of engines mentioned above it will be readily seen in what way the complications arise.

Let us consider the steam-engine installation first, and briefly at that, for it has not been extensively used, and will probably be dropped entirely. The plant comprises an engine and a boiler for generating the steam. The boiler consists of an upper and two lower drums connected by tubes, so that water fed to the lower drums is heated in the tubes and flows to the upper steam drum. The steam then passes to a nest of tubes placed in the region of greatest heat in the boiler, where it is "superheated"—that is, its temperature is raised considerably, whilst, since it is in free communication with the steam drum, its pressure remains the same. The steam then passes along a main steampipe to the regulating valve which controls its admission to the engine. The heating

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of the boiler is effected by burning crude oil, which is ejected from a number of nozzles situated inside the furnace-doors, and immediately below the tubes.

Two points must now be clearly grasped. One is that for combustion of fuel, whether it be oil, wood, coal, petrol, or the like, a supply of oxygen is necessary. Now the air contains oxygen as one constituent in its mixture of gases, so that, as there is always a plentiful supply of air when a vessel is at the surface the oxygen necessary for combustion is obtained in a diluted form by using air. The second point is that as a result of combustion poisonous gases are evolved which cannot be allowed to permeate the atmosphere of a closed vessel, but must be carried overboard.

The supply of air for the crew when a vessel is submerged is limited, it is therefore highly undesirable, if not impossible, to draw from this supply for the boilers; and special pumps must be employed to force the exhaust furnace gases overboard, and precautions taken against any of these gases leading to the interior of the ship. Both these difficulties could, no doubt, be overcome, but one could not rely on any method adopted. Any breakdown in the smallest degree would be disastrous. It would therefore appear that the use of a boiler of the usual kind is not possible for submerged running.

In order that steam be available for the engines for submerged running, a boiler which does not depend on combustion must be fitted. To this end a soda steam generator is used, which consists of a reservoir

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containing an absorbing agent, such as soda lye, and surrounded by a water reservoir. The exhaust steam from the engine is led to the soda lye, where it is absorbed, and its heat stored up and used for heating the surrounding water, which thus generates steam. This system has been tried in the German and French navies, but not in our own.

Where internal combustion engines are used, the same problems as to the air-supply for the fuel are involved. These engines are in this case only used for surface running, and electro-motors are used for the submerged running.

In the earlier boats the engines used petrol as the fuel, and all of them were multi-cylindered, and operated on the four-stroke cycle. Each cylinder of close-grained cast-iron is enclosed in a water-jacket. It is open at its lower end, where it is bolted to a crank-case, and is closed at its upper end, which is enlarged, and provided with valve-pockets, with passages leading to the fuel-induction pipe and exhaust-pipe for the used gases. Valves *c* and *d*, operated by cams as in Fig. 6, control these passages, the cams being driven by gearing from the crank-shaft. The crank-shaft is coupled by means of a connecting-rod to a piston, *b*, which reciprocates in the cylinder. A sparking-plug for igniting the fuel at the correct time and causing an explosion is fitted to the top of the cylinder, the enlarged portion of which is known as the "combustion space." The fuel-induction or inlet pipe is fitted with a carburetter, which provides for the supply of a correct mixture of petrol vapour and air necessary for combustion.

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Reference has been made to the four-stroke cycle. Perhaps it would be as well to go into this in detail. When a number of parts co-act so that a particular set of movements or operations are continuously re-

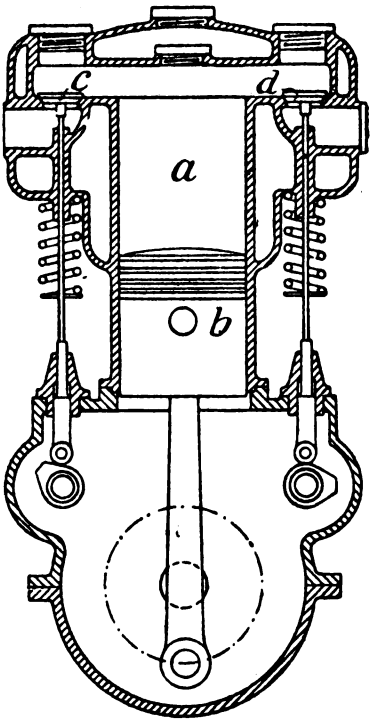

FIG. 6.

peated, each set is known as a "cycle." If in an engine a complete cycle occurs during every four strokes of a piston—that is, during two up and two down movements—the cycle is known as the "four-

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stroke cycle." Now, for a petrol engine the four strokes are as follows:

Inlet or suction stroke.	Piston moves down in cylinder	Inlet valve open; exhaust valve closed.	Mixture air and petrol vapour drawn in from carburetter.
Compression stroke.	Piston moves up.	Inlet valve closed; exhaust valve closed.	Mixture compressed in combustion space.

When the piston reaches the top, a spark is produced at the points of the sparking-plug and ignites or explodes the compressed mixture.

Explosion or firing stroke.	Piston moving down.	Inlet valve closed; exhaust valve closed.	The explosion drives the piston down.
Exhaust or scavenging stroke.	Piston moving up.	Inlet valve closed; exhaust valve open.	The used gases are driven out.

The conditions are then as at the start, so that the next stroke is the suction stroke of a fresh cycle, the cycle being repeated indefinitely.

The engines are much the same as motor-car engines, only slight alterations being made to suit the requirements, such as ready accessibility of *all* parts without disturbing other parts. Difficulties arise in handling such a highly inflammable substance as petrol, and precautions have to be taken that no leaks can occur, and no free sparks exist likely to ignite stray petrol vapour.

In later boats crude-oil engines of the Diesel type have superseded the petrol engines, and as far as the

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fuel is concerned there is an undoubted advantage in respect to safety, and also in respect to the magnitude of the radius of action of such boats.

In the D and E types, two Vickers four-stroke Diesel type engines, each of eight cylinders, with a maximum number of revolutions per minute of 450 are installed. The Diesel engine differs from that already described in two or three details. On its suction-stroke, only pure air is drawn in, and this is compressed on the compression-stroke up to a pressure of, in some cases, 500 pounds per square inch; whereas in the petrol engine the mixture of petrol and air is rarely compressed above 100 pounds. The highly compressed air is so hot that the fuel, which is forced in during part of the firing-stroke by a pump, past a fuel-injection valve, is ignited, and burns steadily, operating when the supply is cut off during the latter part of the stroke by expansion. A sparking-plug is therefore not necessary.

Due to the high temperatures, it is necessary to not only water-cool the cylinder, but also to cool the piston, otherwise it would become distorted and crack or expand, and "seize up"—that is, stick in the cylinder. And it is this same temperature difficulty which prevents the use of "double acting" engines of any size.

In double-acting engines, the bottom of the cylinder is closed, so that the lower part of the cylinder can be used as a combustion space, like the upper part. The piston-rod then passes through an opening in the lower cover, which has a stuffing-box for preventing the escape of gases.

By arranging for the changing of the cams operating

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the valves, it is possible to set the engine running in the reverse direction for going astern.

Now, another type of Diesel engine is used which operates on the two-stroke principle—that is, the four operations, suction, compression, firing, and exhaust, are performed during every two strokes of the piston, or one revolution of the crank-shaft. The fuel-valve is in the head of the cylinder, whereas the exhaust-ports are at the bottom of the cylinder, being covered and uncovered by the piston, which thus acts as the valve. A second valve in the head controls the supply of compressed air for " scavenging " the cylinder—that is, for assisting in the forcing-out of the used gases. In addition, the air remaining when the exhaust-ports are closed again is that used for compression up to the calculated pressure.

The method of obtaining the scavenging air varies, but two different forms are in general use. Separate cylinders, with pistons driven off cranks on an extension of the main crank-shaft, act as the air compressors; and it is this form which is largely adopted with submarine installations, for the resultant longer engine does not present such design difficulties as the engines embodying the other form. It must be borne in mind that the head-room is limited, so that anything adding to the height of an engine is an objection to its use. In Fig. 7 is given a diagrammatic view of the cylinder of an engine of the second type, from which it will be gathered that the upper part, *T*, acts as the power cylinder, and has a fuel inlet, *F*, air-scavenging opening, *S*, and a ring of exhaust-ports, *E*, with which the upper part, *B*, of the " stepped " piston

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co-operates. Now, the annular part, *C*, of the cylinder casting together, with the annular part of the piston functions as an air-compressor for providing the scavenging air, suitable inlet and outlet ports being

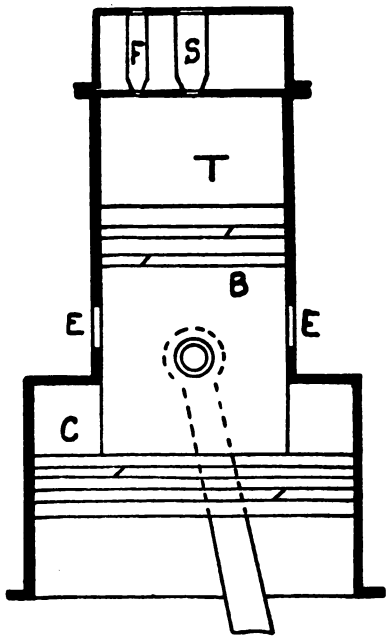

FIG. 7.

provided. The pressure of the scavenging air is from 3 to 7 pounds per square inch.

The engine illustrated in Plate XI. gives a very good idea of a Diesel engine with the various auxiliaries. The Krupp two-stroke Diesel here shown is of the kind installed on the German submarines U 25 to U 30,

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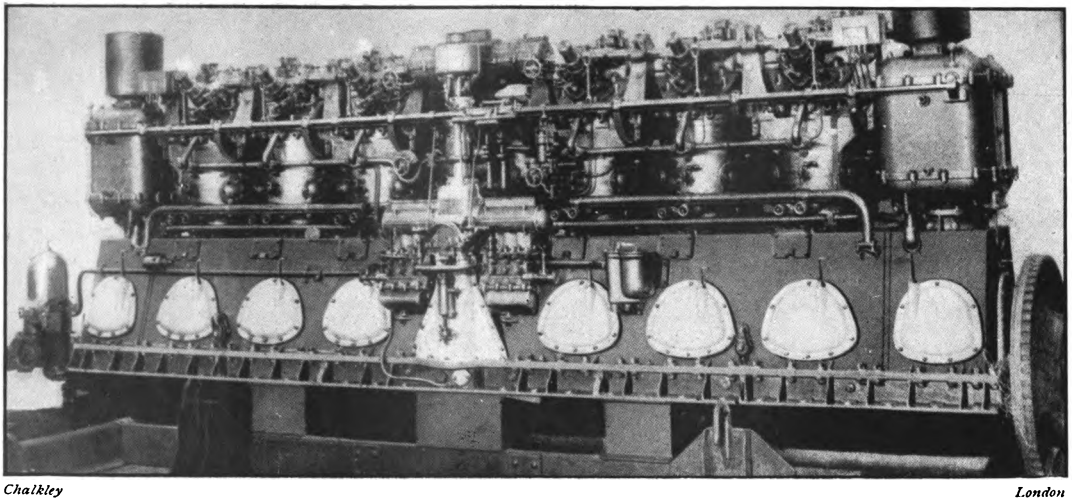
PLATE XI.



Chalkley *London*

DIESEL ENGINE, 900 HORSE-POWER. SIX-CYLINDER TWO-STROKE

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which develop 900 horse-power at 450 revolutions per minute. There are six main power cylinders of the single-acting kind, grouped in two sets of threes, between which are two air-compressors, and at each end are the scavenging-pumps, making in all a line of ten cylinders.

The valves are placed in the cylinder-heads, which are detachable from the body of the cylinder, and are inclined so as to be grouped about the cam-shaft. The engine is directly reversible, for which purpose separate ahead and astern cams are fitted for the fuel and scavenging valves, whilst a sliding cam is provided for the air-starting valve. All the controls are grouped at the centre of the engine; they can be seen in the neighbourhood of the lubricating-pumps and leads. Large doors are fitted to the crank-case for facilitating adjustments or repairs to the crank bearings, big ends of connecting-rods, piston-cooling apparatus, and similar other parts needing periodical attention.

An interesting set of data is given in Brassey's "Naval Annual," in which it is stated that up to the present the maximum horse-power obtained per cylinder from a two-stroke engine is 170 brake horse-power, and from a four-stroke engine is 100 brake horse-power. For higher total horse-power eight cylinders instead of six are used, and three sets in place of two. The average weight of the engine is about 70 pounds per brake horse-power, but this is being reduced. The horse-powers for the various types of submarines have already been given in Chapter II.

It is usual to test these engines, so as to find out the actual amount of energy available at the crank-shaft

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for power purposes, and as it was usual to determine this by absorbing the energy by a brake in such a manner that the measurement was easy, the power is generally called the " brake horse-power," for which the initials B.H.P. are familiarly used. The calculation is dependent upon the assumption that 33,000 foot-pounds of energy given out each minute is equal to one horse-power.

When running submerged, the propeller-shafts are driven by electric motors, which take their energy from storage batteries. As previously mentioned, these batteries are charged by a dynamo driven by the main or an auxiliary engine when the boat is floating light.

The batteries consist of a number of cells containing a liquid in which are immersed a number of honeycomb plates. The interstices in the plates are fitted with chemicals in a pasty condition.

These batteries are of two main types—acid and alkali—the division being made in accordance with which kind of liquid or " electrolyte," as it is sometimes called, is used. Formerly, acid batteries only were used; but now there is a growing use of the alkali type. The much-talked-of Edison battery falls into the newer alkali group.

The general proposition involves a number of stages at which energy in one form is changed into energy of another, and as energy in a useful form is lost at each stage, it will readily be seen that the more stages or transformations, the more energy is lost. So that one must not expect so much from a secondary source of power as from an original and primary source.

First, there is the prime mover, or engine, which

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gives out mechanical energy that is changed into electrical by a dynamo, which electrical energy exhibits itself during the charging of the batteries in a chemical form; and when the battery discharges the chemical energy is again changed into electric energy for driving the electro-motor.

In acid batteries the cells are lead-lined boxes containing a solution of sulphuric acid and water in the proportion of 1 to 4, and the plates, or " electrodes," are grouped in two sets placed alternately, and referred to as " positive " and " negative " plates. The alternate plates are coupled, as shown in Fig. 8. When

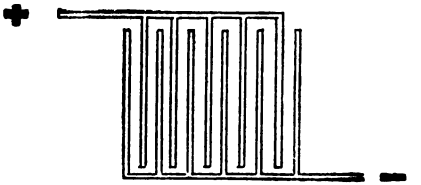

FIG. 8.

an electric current is supplied to or given out at the terminals—that is, when the battery is being charged or is discharging—chemical changes occur.

When in a " charged " condition—that is, when in such a state that they cannot usefully be coupled to the dynamo which supplies electricity, but can be coupled up to the electric motor to supply it with electricity, the negative plates consist of pure spongy or porous lead, and the interstices of the positive plates contain lead peroxide.

During charging, current enters the cell at the positive plate, passing through the liquid to the

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negative. The liquid is split up, and oxygen is carried to the positive plate and hydrogen to the negative. Current flowing through the electrolyte breaks up the liquid, and hydrogen and oxygen are freed.

On discharging, the lead of the negative is converted into a sulphate, and the hydrogen goes to the positive, and breaks the oxide into a lower one, which then forms the sulphate. On charging, the hydrogen passes to the negative, and breaks the oxide down completely, leaving the pure lead, whilst at the positive the oxygen changes the sulphate back into a peroxide.

An alkali battery such as the Edison has for its electrolyte a solution of caustic potash in water in proportions 1 to 5, the plates being nickel hydrate and iron oxide. The cells are of steel with welded edges, and have an airtight cover, a valve being provided for the escape of gas.

An English make is the Alklum, which is manufactured by Worsnop and Co., Ltd., Halifax. The following description is taken from their catalogue: The positive plates are of oxyhydrate of nickel mixed with graphite, and in the negative plates is an alloy of iron and cadmium in a very finely powdered slate, this alloy being mixed with certain other substances. The inactive retainers which hold the active material are made from two very thin bands of sheet nickel finely perforated. The case, or container, is of sheet steel with welded seams. The electrolyte comprises a 20 per cent. solution of caustic potash.

In comparing the two forms of battery, this newer type is the lighter; the more durable, both chemically and mechanically; can be left unused for long periods

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without deterioration; and cannot be injured by overcharging, or by excessive rates of charging or discharging. Against these advantages must be weighed the disadvantages. It is costlier, but this of practically no moment when the Government are the buyers, and when the efficiency of the Navy is in question. Each cell is less powerful—*i.e.*, it has a lower E.M.F.—and immediately it is called on to do duty there is a marked drop in the E.M.F.

There is one other point to be considered when the battery is for submarine use, and that is vividly recalled to mind when the official reports on accidents to submarines are remembered. If a boat develops a leak, whether from accident or from other cause, so that salt water gets into the boat, in the case of acid batteries as soon as the salt-water saturates the batteries, then chlorine gas is given off which is highly dangerous to the crew. No ill-effects of this character would result when an alkali battery is used, and one feels justified, therefore, in regarding this point as one of considerable importance.

Ventilation.—In order that the gases given off under certain conditions by the batteries shall not accumulate, electrically operated fans are employed to clear them away, and a similar set is used for making sure that all gases from the engines are cleared away. Some of these gases must be got rid of because of their poisonous character, and others because of their inflammable nature.

Electro-Motors and Dynamos.—For submarine use a readily reversible type of electric machine should be employed, and it should be efficient under both condi-

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tions, whether run as a dynamo or as a motor. It must be a machine which can be mechanically driven, and when so driven will create electrical energy, and thus act as a Dynamo; and at the same time, by the movement of a simple switch, the electrical machine must be able to receive electrical energy and convert it into mechanical, and so act as a Motor.

Broadly speaking, there are three main parts to these electrical engines: (1) An armature; (2) a frame carrying pole pieces and electrically excited magnets;

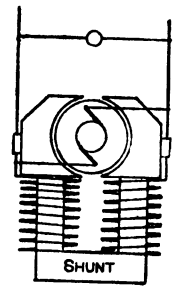

FIG. 9.

(3) commutators and brushes. The armature usually rotates between the pole pieces, and both are wound with many turns of insulated wire when of the shunt-wound type.

The excitation of the magnets of a two-pole dynamo is effected by current passing along coils of wire known as "field coils," Fig. 9, whereby North and South Poles *N.* and *S.* are made to exist. The armature is rotated in the "sphere of influence" between the poles. It consists of a cylinder built up of a number of plates insulated from each other, having

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slots in which are placed coils of wires, the ends of each coil terminating in opposite copper segments of the commutator, from which electric current may be collected by arms, known as "brushes." Upon rotation of the armature, currents flow in the wires, the force of which, or voltage, being dependent upon the design of the machine.

In the shunt-wound type of machine the field coils are connected across the main terminals of the armature circuit, so that the strength of the magnets is dependent

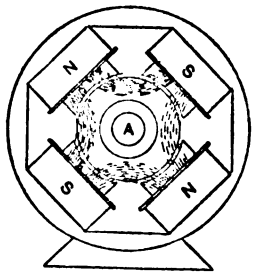

FIG. 10.

upon the machine voltage, and is not directly effected by the load on the external circuit.

For varying the speed of the propeller, when the machine is acting as a motor, whilst maintaining the voltage constant, a series of resistances, or rheostat, is introduced into the field-coil system.

On our submarines the motors are of the four-pole type, of which Fig. 10 is a diagram, wherein the lines of force, or "spheres of influence," are indicated. Although brought to a very high state of perfection, the most frequent cause of inefficiency and trouble is

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the very one which is most dangerous for an enclosed space. Sparking at the brushes is caused by an imperfect contacting of the brush with the commutator segments, and the imperfection is generally due to uneven wear of the carbon, or to a slackening in the tension of the springs which holds the brush down on to the commutator. The danger that arises from the existence of a spark must be apparent in view of the possible existence of inflammable gases.

Whilst not going deeply into the technical side of the propelling plant, it is hoped that the foregoing matter will be of interest to technical students, and yet be of interest to and not above the heads of the general reader.

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CHAPTER VI

THE TORPEDO

THE torpedo is an offensive agent, which has to be aimed at an enemy ship, and is thus broadly distinguished from a mine, which, in reality, is a defensive weapon, and, once laid, it is left to chance as to whether it finds a victim; but in both cases the objective is the same—the firing of a charge of gun-cotton or similar explosive beneath the hull of the ship.

Of the many different types proposed and used from time to time, one stands out pre-eminently in the English Navy at the present moment—it is the Whitehead. As a result of years of patient study and application to the correction of details, the modern torpedo has been brought to a marvellous pitch of perfection. In the beginning these weapons were exceedingly erratic in behaviour, and many little ingenious mechanisms have been embodied which have reduced their defects to a minimum.

Notwithstanding their intricacies, an endeavour will be made at presenting the main features in a clear manner.

The torpedo is ejected from a tube in the ship by compressed air, and aim is taken by placing the axis of the tube along the required direction, as will be explained later.

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The torpedo is an automobile, inasmuch as it has its own propelling engines and screw propellers, and also rudders for controlling the direction of its motion. The general outline of a torpedo is not unlike that of the submarine itself. It is divided into compartments in a similar manner, and in recent types the nose has a more blunt formation than in the earlier ones, for the same reason as that already referred to at p. 10, in connexion with the shape of the submarine.

The main types now in use are made of steel plating or phosphor-bronze, and have diameters of 18 inches and 21 inches, the length being 18 feet and 21 feet respectively. In making the length as many feet as the diameter is inches, a constant ratio has been approximately kept to from the early types onward.

The dummy head or nose of practice and peace-time is replaced in other times by a war-head, which contains 200 pounds and 330 pounds of explosive charge for the 18-inch and 21-inch respectively. The 21-inch Schwartzkopf torpedoes used by the German Navy contain 290 pounds of charge, but its explosive value would seem to be greater than ours. This head is furnished with a projecting rod, which, when the torpedo strikes a hard substance, is driven in on to a detonating charge—usually fulminate of mercury. The sudden knock changes the state of the mercury compound, which expands so rapidly that it acts with an increased force upon a small quantity of dry gun-cotton, known as a " primer," situated approximately at the centre of the main charge. The primer is exploded, and by its expansion detonates the main charge.

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Motorists and others using petrol engines know that the explosion in an internal combustion engine may take place almost instantaneously, or may act so slowly that one charge of fuel mixture is not completely burnt by the time the next is admitted. He knows this latter fact because when the inlet-valve opens to let in the new charge, the old burning mixture ignites it and passes down the inlet-pipe to the carburetter, causing " popping back." Most people also know that if gunpowder be loosely placed on a board it can be ignited, and will burn quietly, whereas if rammed into a toy or other cannon, when ignited, it goes off with a bang. The slower kind of burning is technically known as " combustion," whereas the rapid burning, which is almost instantaneous in action, is known as " detonation," and is accompanied by very much greater explosion pressures.

The pointer or striker rod is provided with a revolving fan, which screws itself off a small length of thread when travelling through the water; and until it is off, the fan boss acts as a collar to prevent the rod moving back into the torpedo. An accidental blow when shipping or transferring the torpedo to the expelling mechanism does not necessarily result in an explosion, bringing in its train resultant damage to one's own boat. An additional safeguard against movement of the pointer is provided by a pin which is screwed into the rod, and which can only be broken off upon the rod receiving a fairly strong blow.

The main charge of explosive is put in with a certain amount of water, roughly about 20 per cent., and

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is made up as a mixed mass, although formerly it was placed in the head in laminated blocks.

The air-storage chamber is placed behind the head, and is cylindrical in shape, with dished ends. It is made from the best steel, and with a thickness of $\frac{5}{16}$ to $\frac{3}{8}$ inch, for it has to stand up to 2,500 pounds of pressure per square inch. The air may be pumped in by a compressor through a special opening, but the supply is usually obtained from the air-storage tubes, which also form the store for use in the emptying of the ballast tanks, and similar duties.

The casting which contains the filling valve also contains the starting valve. This valve is opened, when the torpedo is started on its run, by a cam actuated from a lever coming through the shell, the lever being knocked over by contact with a projection in the launching-tube. If the air were to pass directly to the engines which actuate the propellers, the propellers would then be revolved in the air in the tube and until the torpedo was totally immersed in water. The result would be that, owing to the smaller density of air, the propellers would momentarily revolve at a rate much above their designed speed, and be subjected to the consequent risk of their breaking. To overcome this defect, the air which has got past the starting valve is not allowed to get as far as the engines, but is prevented by a delaying valve, which only opens when the torpedo enters the water. This is effected by connecting the valve lever to a plate, which is swung over by impact with the water.

When a chamber is stored with air at a pressure of 2,000 pounds per square inch, the act of drawing off

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Cribb *Southsea*

LOWERING A TORPEDO THROUGH THE SUBMARINE HATCH

To face p. 64

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air for power purposes gradually diminishes the pressure, and it is not hard to follow that, if the air were supplied under these varying conditions to the engine, its speed and power would correspondingly vary. A very old engineering device, known as a "reducing valve," is therefore used. The engine is fed with air at a constant and reduced pressure, and its speed and power consequently remain constant, or nearly so, during the run.

All these valve actions take place at predetermined times or under predetermined conditions. There is one other automatic action which must be described in connexion with the "power plant." It is known to most of us that, when pumping up the tyres of a bicycle, the pump gets uncomfortably hot. Now, in the same manner, if one expanded a gas, instead of compressing it as in the pump, there would be a cooling effect. To go one step further, if as one expanded a gas the natural tendency to cooling is counteracted by an independent heating influence, it would be found that the work got out of the expanding gas would be increased.

This fact is now made use of in the torpedo, for a supply of oil is fed to the air chamber, and a small sparking device is used to ignite the jet of oil at the moment of launching, the heat of combustion having the good effect described. The net result is an increase of 30 per cent. in the speed of the torpedo for a given range.

An 18-inch torpedo is capable of covering 6,000 yards at twenty knots, 2,500 yards at twenty-eight knots, and 1,000 yards at thirty-six knots. The latest 21-inch tor-

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pedoes are said to have a range of 12,000 yards, the speed at the commencement of the run being forty-eight knots.

We now pass to the engines and propellers which render this speed possible. The engines are situated in a chamber which is separated from the air chamber by one known as the " balance chamber," and on the other side is the buoyancy chamber, which is the one forming the tail-piece. A three-cylinder engine is used, developing from 35 to 50 horse-power, but these engines are quite likely to be replaced by turbines in the near future. The inlet valve comprises a rotary plug, controlling all three cylinders. The exhaust in passing from the torpedo bubbles up through the water to the surface, and thus gives a very valuable notice of its presence to observers. The engine shaft passes along a tube through the buoyancy chamber to a bevel-wheel gearing, whereby an inner solid shaft, carrying one propeller, is revolved in one direction, and an outer hollow shaft, carrying a second propeller, is rotated in the opposite direction. By dividing the power between right-handed and left-handed four-bladed propellers, the reaction due to the " torque," or turning moment, is balanced. When only one propeller was used, there was a tendency for the torpedo to heel over under the reaction.

Having dealt with the propelling mechanism, the steering mechanism for the two horizontal and two vertical rudders remain to be dealt with.

In the steering two points have to be considered; one is the control of the vertical rudders, whereby the torpedo is kept on its course, and the control of the

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horizontal rudders, so that it keeps its depth, and also maintains its axis in a horizontal position. Both controls are housed in the balance chamber. The course is kept by employing a gyroscope, the heavy rim of which is put into rapid rotation by a spring motor or air engine at the moment of launching. If one recalls to mind the shilling gyroscopes which seem to be on sale at all and sundry exhibitions, it will be remembered as a property of this interesting mechanism that, no matter in what position the axes of the spinning wheel may be, there it will stop as long as the rotation is kept up. This property of the gyroscope is utilized in the torpedo, for if the latter tends to go off its course, there is relative movement between it and the former, which movement brings into play a system of levers connected with the rudders, or moves the valve of an air engine used for moving the rudders. The rudders are moved, and bring the torpedo back on its course until the gyroscope axis and torpedo axis are in their original relationship, by which time the levers have moved the rudders back to the central position.

There are two vertical rudders and two horizontal rudders, pivoted in a frame which encircles and protects the propellers.

The horizontal rudders are controlled jointly by a hydrostatic device of a kind similar to that already described on p. 37, and a pendulum device. When the axis of the torpedo is inclined to the vertical, a pendulum swings fore and aft into a new position, and is coupled to the steering-gear, so that the rudders are inclined and the horizontal position restored.

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When the depth of the torpedo changes, a small piston, which is pressed inwardly by an amount dependent upon the depth and outwardly by a spring, is moved to new positions of equilibrium, and so moves the steering-gear. The connexions of these to controls is not directly by rods to the rudders, but to a valve, which operates a small air motor, which in turn acts on the rudder. This little intervening mechanism is known as a "servo-motor." The engine is essential, as the power necessary to move the rudders against the pressure of the water is very large, due to the high speed of movement through the water. By adjusting the spring—a simple screwing action being all that is necessary—the depth at which the torpedo is intended to run can be decided upon.

For practice purposes a train of wheels is moved by the engine shaft, and so arranged that a lever is brought into position to move the cam of the starting valve to the shut position corresponding to a given desired distance of travel of the torpedo. The practice torpedo, being buoyant, then simply floats to the surface.

A general view of a complete torpedo is given in Fig. 11.

B is the balance chamber, containing the gyroscope, *G*, and servo-motor, *S*, which co-act with a pendulum (not shown). *C* is the air-pressure chamber, and *F* the fuel for heating the stored air. *V* is the valve chest containing the stopping and starting valves and the charging valve. *I*, are external guide-pieces, for use when discharging the torpedo from the tube. *H* is the head containing the charge, *P* the projecting-

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point or striker, and *D* the chamber containing the detonating charge. The engine, *E*, drives a shaft, which through a train of wheels, *T*, operates the two propellers. The frame for the rudders encircles the propellers. *R* is a buoyancy chamber. The torpedoes are slung down through a hatch into the submarine as depicted in Plate XII.

Torpedo-Tubes. — Of the many types of torpedo-launching apparatus in general use, only one form is now carried on submarines—that is, the submerged tube. One other kind has been used in isolated cases, the torpedoes being held in cradles, or jaw-like members outside the ship. The jaw members are opened by a longitudinally sliding bar, which also sets the propellers revolving, and the torpedo propels itself in the desired direction.

The launching-tube is made of gun-metal, has a cover at its outer end practically flush with the plating of the ship, a cover at its inboard end, and also, in some but not all cases, a door in the cylindrical side. The inner surface of the tube has grooves which act as guides for the fins (Fig. 12, *I*) on the torpedo; and there is also a projection for operating

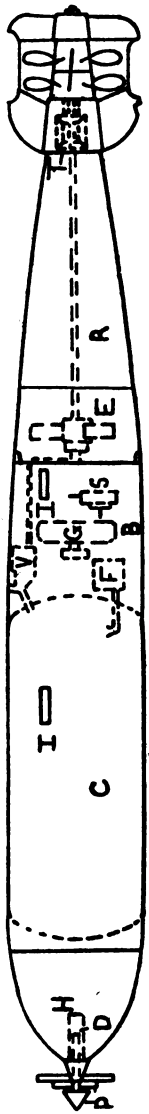

FIG. 11.

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the starting valve and a drain-pipe. The torpedo is expelled by compressed air at about 500 pounds pressure, the outboard cap having been previously raised. After the discharge the tube is filled by water, which serves to maintain the trim of the vessel, replacing the lost weight of the torpedo. The cap is then closed again, and the water in the tube is forced into a reservoir, in preparation for launching a second torpedo. These tubes, as can be seen from Fig. 4, are fixed relatively to the ship, so that aim has to be taken by pointing the head of the vessel in the direction it is desired the torpedo shall take. A likely development would appear to be the fitting of adjustable tubes in side chambers or "Sponsons" on the vessel, the aim being made with the tube and not the vessel.

Guns.—The only information available with respect to the guns carried on submarines is that relating to the German boats; but, as far as is known, our own constructions are not unlike those made by Krupps. The broad statement that so many 3-inch or 4-inch guns or 12-pounders are carried is all that has been disclosed officially.

The Krupp gun is of the 7·5 centimetre type, which in English measurements is 2·95 inches, and therefore is the counterpart of our 3-inch gun. Normally it is housed with its axis along a position *b*, *b*, Fig. 12, in a compartment situated in the space between the twin hulls, or immediately below the upper deck and the shell of the boat. The gun rests on a spring, *S*, and is kept in place by two doors, *C*, held by a sliding and spring-controlled locking-bolt. No attempt is

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made at keeping this compartment water-tight. The gun is suspended in trunnions, *T*, in an open frame, *A*, which is pivoted to a pedestal on the upper deck. When the locking-bolt is released, the gun is swung up by the spring, *S*, pushing the doors, *C*, away, and takes up the position with its axis, *a*, *a*, in the position shown. Spring-catches on the pedestal, *P*, automatically lock the frame, *A*, in position. The sights are rapidly fitted and the gun is then ready to be fired. On a trial it was found that the whole operation of unhousing and training the gun occupied twenty

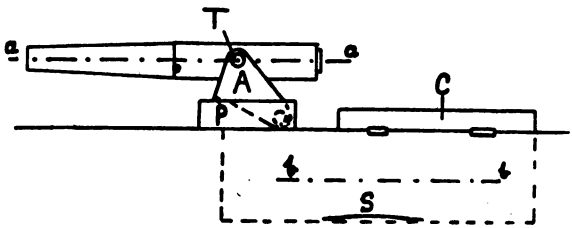

FIG. 12.

seconds. The frame, *A*, is made open, so that the gun can be trained vertically when it is desired to fire at air-craft. The gun is made of nickel steel, and the weight of the gun and mounting is 860 kilogrammes, which in English measure is 1,895 pounds.

These guns were originally installed with a view to giving submarines the power of coping with attack from air-craft and torpedo-boats, but a new use is now being made of them. They are used for intimidating the crew of a merchant-ship and making the ship lay to whilst some of the submarine crew inspect the ship's

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papers. A collapsible boat is used for the purpose of conveying the examining crew to and from the merchantman. Should the ship prove to belong to an enemy country, it can be sunk by gun-fire, instead of using the expensive torpedo, and so depleting a stock which is never any too large.

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CHAPTER VII

NAVIGATION FITTINGS

SOME interesting accounts have from time to time been given by men as to their first experience of going below the surface in a submarine, and in most cases one is struck by the fact that they had little or no idea of the subject which physicists call "light." The younger generation, however, is learning about light-rays and the reflexion and refraction thereof, and in what manner these rays are affected by prisms and lenses. Without any such knowledge, it is known to most of us that it is practically impossible to see when below water, and so the occupants of a submarine have to employ an "external eye" when running submerged. This instrument is known as the "periscope."

The periscope is a form of telescope for observing from submarine or submersible boats distant objects which cannot be viewed directly. It comprises a rotatable reflector (or combination of reflectors may be used), so as to sweep the horizon, and an erecting prism which is used to project upright images at a fixed point within the vessel.

The reflector is carried in an upright tube, which is rotated by gearing, and means are provided for raising or lowering the tube. Altering the height is necessary

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likely to give its presence away, for even the small wash created by the periscope may betray one (see Plate VII.), but if it is only existent for quite brief periods with relatively long intervals, then the risk of detection is considerably lessened. When the periscope is submerged, the vessel can only be manœuvred in accordance with the calculations of the commander, based on the speed of his vessel and the flow of the currents. If the movement is one of attack on an enemy vessel,

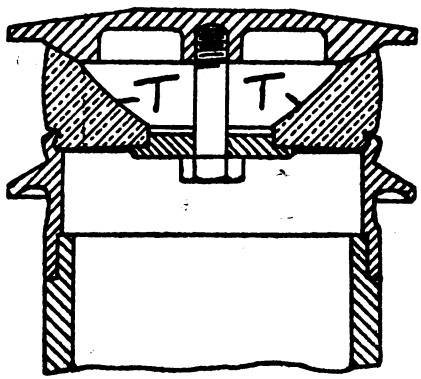

FIG. 14.

then the speed and direction of movement of that vessel must also enter into the problem.

The complete periscope shown in Fig. 13 is one designed by Sir Howard Grubb. There is an upper reflecting prism, below which is a lens or objective, and below this again is a lens or condenser, preferably achromatic. For magnifying the image and enabling it to be seen at a vertical eyepiece, a reflecting prism and telescope lenses are used. By this combination also the image obtained is erect.

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When an all-round view is desired, the upper reflector is shaped as shown sectionally in Fig. 14.

The difficulty with such lens-mirror reflectors is that the horizontal and vertical dimensions of the image obtained are not in the same proportions to the original. If a true to scale image is wanted, the reflecting surface, *T*, has to be a toric surface—that is, the radii of curvature of the surface measured in two perpendicular planes are unequal.

The mirror, with its angle of vision of about 60 degrees, has to be rotated for viewing the whole horizon, and the central prism is rotated at half the speed in order that the observer at the fixed eyepiece shall always receive an upright image.

Since the height of the periscope is not very great, the range is limited, and in a heavy sea the view may exist for short periods, with intervals in which it is obscured entirely. Anything in the nature of a fog or mist renders navigation by periscope impossible. There are graduations on these instruments which enable some amount of range-finding possible.

In modifications of the original type two sets of gears are proposed, which are used in this manner. When taking a rapid view, such as when sighting an enemy, and upon rising to use the periscope, the fast gear is used to bring the instrument quickly to the approximate position, and then the slower gear for keeping the object in the field of view.

Compasses.—Each modern boat is fitted with two compasses, one outside the hull for steering when running light, and one inside for aiding in submerged steering.

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The outside one is of the ordinary magnetic type used for general navigation, and needs no explanation. The inner one belongs to an entirely new class, having the properties of a gyroscope. Anschutz and Sperry have been the principal investigators, and have brought this instrument to its present stage of perfection. It must be remembered that the rotation of the earth is changeless and undeviating, and that a large rotating wheel resists any tendency to being shifted relative to space. This resistance or inertia therefore operates to maintain the original plane of rotation fixed with relation to space, and a known quantity in relation to the earth. In the gyro-compass the axis of a rotating wheel is initially positioned along the north and south meridian. Now, the frame on which it is mounted, being fixed to the ship, moves with it. Consequently, relative movement of the gyro-axis and the frame affords a ready means of knowing the direction in which the ship is heading. The E class boats are fitted with a Sperry gyro-compass.

If an ordinary horseshoe magnet be placed beneath a quantity of iron filings resting lightly on a piece of paper, it is known that the filings group themselves between the pole pieces of the magnet in a very definite manner. Should the experiment be extended to the case when a piece of soft iron is placed between the poles, it will be noticed that the iron filings crowd more toward the region of the soft iron. Had the soft iron been a hollow cylinder, then the central part would be practically free from filings. This simple experiment shows the underlying principle which determines why a magnetic compass is not used inside

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a submarine. The iron of which the submarine is largely built would utterly upset the influence of the earth's magnetism upon the needle of any magnetic compass. With the coming into existence of the need for another kind acting on an entirely different principle, there has also risen the investigators able to meet the demand—a feature which may be noted over and over again in modern life. There are not so many cases of inventors and investigators being before their time. There are so many developments in different directions which demand original thought and patient investigation, and which have marked and, in many cases, magnificent possibilities, that the inventive faculties are sufficiently excited and taxed with them, without giving time and thought to matters having no immediate future, and for which a demand does not exist, but has to be created.

Buoys for communicating with, indicating the position of, and raising, sunken vessels have been a very fruitful source of invention. It is, however, a very moot point as to whether it is worth while fitting them. Accidents to submarines are so very few and far between in any case, and of these in fewer cases still would the loss of life and material have been lessened by the fitting of buoys of this character. The space occupied and weight of the buoy and its housing may be more effectively given over to other articles of equipment of value to a submarine as a fighting machine.

Argument has been brought forward that in the present state of the development of submarines every means for eliminating their defects should be employed; and that if the fitting of a buoy leads to the

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salvage of a sunken submarine which otherwise would not have been recovered, and thus provides the opportunity for investigating the probable causes of the accident, then the fitting is thoroughly justified.

One such buoy is diagrammatically represented in Fig. 15. The float, *B*, is housed in a well in a submarine, *A*, and secured in position by an automatic locking apparatus.

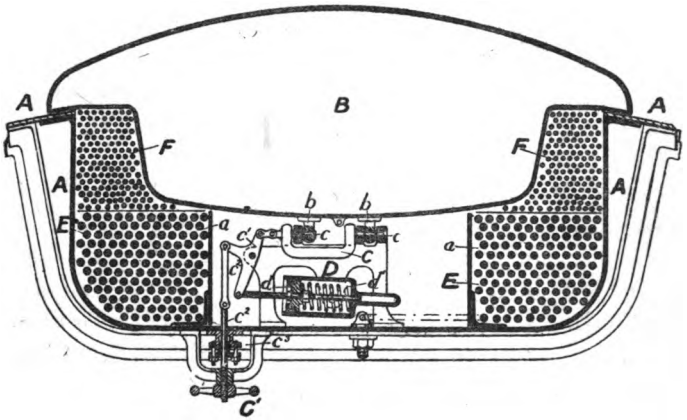

FIG. 15.

The automatic locking apparatus, *C*, comprises a bolt, *c*, which engages with two eyes, *b*, on the buoy or float, *B*, a closed cylinder or chamber, *D*, with a piston, *d*, and spring, d^1, or a diaphragm, d^2, to which the bolt, *c*, is connected by a lever, c^1. The spring, d^1, or the diaphragm, d^2, holds or locks the bolt, *c*, and when submerged below a predetermined distance the pressure of the water acting on the piston, *d*, or diaphragm, d^2, withdraws the bolt, *c*, and releases the buoy or float, *B*.

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The bolt, c, may be connected by a lever and connecting rod, c^2, with a hand-wheel, C^1, inside the submarine, so that the bolt, c, may be withdrawn from the interior should the occupant desire at any time to signal to the surface. The rod, c^2, passes through a stuffing-box, c^3.

In the recess, chamber, or compartment, a, is coiled a strong steel hawser, cable, or chain, E, and a light flexible steel rope or chain, F. One end of the main hawser, E, is made fast to the vessel, and the other end to the light steel cable, F, the outer end of which is connected to the buoy, B.

The buoy not only indicates the locality of the sunken vessel, but enables the salvage vessel to get possession of the chain or hawser for lifting the boat.

Among the many proposals put forward are included those for buoys which carry up electric wires, so that the buoy can be lit with an electric light or that a bell, gong, or other warning sound can be operated; and that when the salvage party arrives telephonic communication with the crew may be established. Tubes also may be used for exhausting the vitiated air from the boat and supplying with fresh air, and even for supplying food.

In place of an electric light, the buoys can be painted with a luminous paint so as to be readily visible, and an ordinary bell, the clapper of which is set in motion by the movements of the buoy, can be used for the audible signal.

Escape Chambers.—An enlargement of the idea of an indicating buoy consists in providing means for the escape of the crew from a sunken submarine.

By forming the conning-tower so that it can be de-

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tached from the main deck, and carry up the crew who have gained access thereto through watertight doors, a ready solution is obtained. In practice, one of the difficulties to be overcome is that of making the connexions strong enough to hold the conning-tower in position under ordinary conditions, and at the same time sufficiently simple to be easily broken. Another point to remember is that the operating gear must be reliable.

Another solution of the problem consists in using an air lock or chamber with doors opening to the sea and boat. The chamber should have drain valves operatable within it and from the boat. Each member of the crew enters in turn the empty chamber from the boat, and closes the door behind him. Water is then let into the chamber until it is up to the man's chin, when he opens the door to the outside water and is shot up to the surface. Each door can be opened and shut to the chamber and from the boat, so that when one person has left the chamber, the men left in the boat can shut the outer door and open the drain valve, and so prepare the chamber for further use.

The crew sometimes have special helmets which fit over the head, and which contain sufficient air for breathing during the ascent up through the water. In Plate XIII. a man can be seen coming up out of the water with one of these helmets on.

Air-Supply, Ventilation, and Habitability.—As the men breathe, so the oxygen of the air (which is necessary to man if he is to live) in the boat is used up, and a poisonous gas, carbon dioxide, is breathed out. The

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chemical symbols for oxygen and carbon dioxide are O and CO_2 respectively.

If the air in a closed vessel is used over a lengthy period, eventually the O present will be reduced, and CO_2 increased to such an extent that life is not possible. The relationship of air with combustion phenomena has been already referred to, and is of an analogous character with the problem now being dealt with.

The supply of air when running light is simple, and a ventilator with fan is all that is necessary to insure a thorough scouring and renewal of air throughout the boat.

When submerged, it is possible to use some of the compressed air stored for ballasting and the torpedoes, but it is not desirable to draw on this supply; as it is, a certain quantity unavoidably escapes into the boat, and thus helps to prolong the time during which it is not essential to deal with the air in the boat. Should the air want purifying, resort is had to the chemical action of certain substances, such as caustic soda, which absorb the CO_2, and of other chemicals, principally potassium oxides, which yield small quantities of O upon solution in water. The extreme limit of time during which a boat can be completely submerged is not known, but in several instances twenty-four hours has been reported as the duration accomplished by a submarine crew without serious ill-effect.

Habitability.—For rendering the boat habitable, the air-supply is dealt with as just described, and, in addition, in the manner and for the reasons given at the end of Chapter V., p. 57. There is also considerable discomfort for the crew in respect of the lack of

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accommodation, because of the limited facilities for exercise, and because the amount of sleep obtainable is very small.

Increased opportunities for sleeping are now being provided by commanders taking the risk of resting the boats on the bottom, and so releasing the men from the continuous demand of navigation. The risks are fairly large, for a hard bottom may result in a punctured skin, and a soft one may be of quicksand nature.

The cooking is done by electricity.

There is no doubt that in the early days the crews were subject to attacks of nerves, owing to the new conditions of living. The shorter boats, besides not allowing a man to move much owing to lack of space, also prohibited his moving owing to the upsetting of the balance of the boat; whereas both these restrictions are removed in the longer boats.

On this question of nerves is founded a very amusing short story by Major W. P. Drury, in which a stowaway parrot plays an important part. The parrot could not be seen by the crew, who were unaware of its existence; so that when it started to recite in doleful tones about the lost souls of the men of the *Royal George* at the moment the boat was passing through the very region at Spithead at which Kempenfelt's boat sank, the crew were so affected that they pleaded with the commander to turn back.

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CHAPTER VIII

ROUTINE ON SUBMARINES

THERE is no such thing as working to a time-table during the war, but the routine work done before the war is followed as far as circumstances allow, and automatically forms part of the plan of campaign in any scheme put into operation. Certain pieces of work must always follow, and be executed in their regular order, and the more perfect the practice, the more does this work take place automatically, and with less strain on the men so employed. One must wait for some time yet before it is possible to know exactly what the conditions of life and work on a submarine are during war-time. These conditions seem to vary from day to day as far as can be gathered, and undoubtedly will continue to vary in a manner which it is impossible to forecast.

Under ordinary conditions, a boat will at some time or another be moored to a boom projecting from the side of the parent ship. Let us assume this to be the case, and, further, that the time is a little before 6 a.m. We should find two or three of the crew on board, and the remainder would be in their hammocks on the parent ship. At 6 a.m. the men turn out, and prepare for breakfast, which is partaken of at 7 a.m.

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One of the seamen is charged with the duty of feeding and attending to the white mice which are carried on every submarine. The mice have been installed as part of the living cargo ever since the accident on the A 5, for they give ample warning of the presence of petrol and like vapours by squeaking, and also give way more quickly than men when the air becomes vitiated, and contains too little oxygen.

Breakfast being over, the crew set to at small duties of the maintenance order. For example, the engine-room artificer, or, as he is familiarly known, the "Tiffy," or E.R.A., goes to the engine-room, and with the help of the stoker tackles some part of the machinery needing attention. The pipe connexions, perhaps, are given new jointing, or a valve is ground in. Maybe the main bearings are noted down as soon needing a dockyard overhaul.

Meanwhile the seamen and torpedo crew are polishing brass and other bright work, or the torpedoes and tubes receive attention. At 9 a.m. (two bells) comes "Stand easy."

If the boat is to go outside for exercises, the oil-tanks are filled. Sometimes this is done at sea, an example being that of the C 3 (Plate XIV.), which is towing a lighter carrying the oil drums. The accumulators are examined, and all Kingston valves are tried to see whether they are freely movable, and rest properly on the valve seatings. The engines are started up, and kept running at a low speed for a short while, so as to get warm and free. Eventually the order comes to let go, and the Lieutenant puts the engine telegraph over to slow ahead; and so the boat puts to

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sea in a light condition, with some of the crew on deck and the conning-tower cover open.

When the exercise-ground is reached, the hand-rails and other detachable deck gear are stowed away, all the crew get below, all the hatches are closed, and the valves at the base of the ventilators or cowls are also shut down. Of the deck crew, one is told off to watch the manometer, or gauge which indicates the depth of immersion of the boat, the quartermaster takes over the steering-wheel down in the boat, and the remainder stand by other details.

The petrol or Diesel engines are then shut down, and the electrical connexions changed over to set the electro-motors going. Next the Kingstons to the main ballast tanks are opened, and the boat submerged on an even keel to the base of the conning-tower; then the horizontal rudders are moved, and the boat goes down as soon as the speed is above about 5 knots. The cruise continues with only the periscope above water, the navigating officer being at the eyepiece at the base of the periscope, and taking his bearings therefrom.

The extension of the cruise by completely submerging the periscope, and proceeding by dead-reckoning, may then take place, and practice with torpedoes gone through. In the latter case, the submarine is accompanied by a tug having mark buoys or targets in tow. As an alternative, the practice may be accomplished with the space between moored buoys as the target. The less experienced hands are instructed in the important duties relating to this work, such as the necessity for filling the special tanks with

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sufficient water to make up the weight of the discharged torpedo, and so preserving the trim.

For training men with no experience of submarine work, it is usual to place two or three new men on board at a time, and go through the diving evolutions. When this has been done, the men are taken off, and replaced by others from the attendant vessel. In this manner the number of men trained can greatly exceed the number necessary for completing the crews of boats in commission, and however fast new boats are put into the effective list, there are always crews ready to take them over. Speaking generally, there are three times as many qualified men waiting for appointment as there are on active submarine work.

Whatever the nature of the practice, be it torpedo or new crew training, the boat is now turned round, and in light trim heads for harbour. Having arrived, the boat is secured to the boom on the parent ship, and if, as generally happens, the time is 3 p.m. (six bells), the crew are occupied with duties incidental to the end of a run until tea-time—4 p.m. (eight bells). This is welcomed more than usual, for it is not improbable that dinner has been either missed entirely, or only a hasty snack partaken of. The tables used are suspended from upper crossbeams in the central compartment of the vessel, and are stowed up against them when out of use, and are thus out of the way.

Work being over, leave is granted, and the lucky ones go ashore.

The day's work varies with occasions, and Wednesday afternoons is usually regarded as "make-and-mend" day, when the seaman turns tailor, or washer-

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woman, or letter-writer. On other days, and when the same crew have been out together several times, more ambitious feats are cautiously attempted, with the idea of gaining knowledge of all the possible properties of the boat. Of course, nothing in the nature of "stunts," such as are performed by airmen, are tried. After the crew are thoroughly at home on their boat, it goes out as one of a flotilla for joint exercises, and the Lieutenant in command works in concert with the commanders of the other boats, and then only evolutions are attempted which previous practice has shown to be sound.

Informal lectures by the officers occupy some of the time, and the men according to their rating attend classes and headquarters set apart for them. For example, the signalling rating does his wireless work at the depot of the *Excellent*. The torpedo men also have their depot. Not only this, but everyone attached to the submarine service has to get used to putting on the special helmet expeditiously, the object of which is to facilitate the escape of the crew through open hatches when a submarine sinks, and cannot be made to come up It is designed on much the same lines as a fireman's smoke helmet, and prevents the death of the wearer by suffocation. For purposes of practice, a large tank of water is used. The men with helmets on climb down the side of the tank, and when at the bottom let go, whereupon they float to the surface. This part of the routine is the least liked of all.

When the submarine service was formed, men were induced to volunteer for it by an offer of two and sixpence per day service money as an extra to the pay of their particular rating. As compensation for the

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extra danger involved, this was then none too much, but it appears to be quite equitable now. One must remember that, apart from the danger of losing one's life by complete wreckage or loss of the boat, a danger now considerably less than formerly, there is the damage to one's general health consequent on the nature of the service. There is not much need to dwell on the temperature of the interior of a submerged boat, as, although it is higher than usual, it is not very much more than the temperature in the stokehold or engine-room of a surface vessel. It is the lack of purity of the air that is the difficulty. Many promising officers have been invalided from this branch of the Service, by reason of the development of chest complaints.

With the larger boats of the latest type, the difficulties encountered are lessened. For one thing, the equipment for purifying the air can be proportionately larger. The later boats, too, have a greater reserve of buoyancy, and, being more truly submersible than submarines, can "steam" on the surface for longer periods and in heavier seas, and so the conditions approximate more to those of the surface vessel, with its induced draughts of pure air. The technical side of the problem of air purification and ventilation generally is discussed in Chapter VII.

Novel as are the conditions appertaining to the submarine service, the British naval men have adapted themselves to them in truly remarkable fashion, and are acquitting themselves with the same proficiency as exists in the other and older established branches of the Naval Service.

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CHAPTER IX

MINES

SHOULD a submarine attempt to force the passage to a harbour, or even when cruising through the open sea, one of the risks it has to run is a mine-field. A mine can best be described as a stationary torpedo, the subdivision into types being usually on the lines of the method of firing them or causing them to explode.

The first type, known as observation mines, are laid in rows, and are fired by an observer, who presses the key or switch of an electric circuit, so causing a whole row of mines across which a boat is passing to be exploded. The nearness of the boat to the mines is determined by noting the position of the boat relative to some floating buoys.

A " contact mine " is one which is designed to explode when a ship contacts with it; and these are of three kinds—electro-contact, electro-mechanical contact, and mechanical contact.

In all these forms the mine comprises a metal casing, which contains gun-cotton, the primer, and detonator similar to a torpedo. The casing is in most instances buoyant, and adapted to be sunk by weights and cables to any desired distance beneath the surface.

The electro-contact mine is one in which the ful-

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minate of mercury is heated by a platinum wire of high resistance, which becomes red hot on the passage of an electric current. The wires forming the main part of the circuit for the current are attached to the moving cable, and led away to some central station. If it is desired to render the mines inoperative—say when one's own ships have to pass over the region in which they are laid—then the circuit is broken by removing

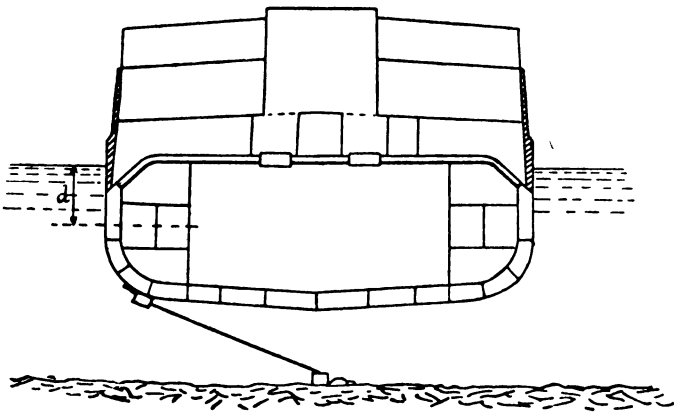

FIG. 16.

switches or keys, situated at the station where the bells, accumulators, or batteries for the circuit are kept.

With the switches or keys of the home station in place, the circuit can be finally completed by the putting into action a switch as a result of the contact of a ship with the mines. Many and ingenious mechanisms for effecting the completion of the circuit are in use. When the mines are grouped, and in order that the firing of one mine shall not break the circuit for the

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others, a small switch or fuse-box is used, which seals over the leads to the used unit. In one arrangement, the passage of the ship causes an iron rod to dip into mercury for completing the circuit, and in case the ship only tilts the mine the movement of the liquid mercury is utilized to effect the closure. This cannot happen, however, unless the angle of tilt exceeds 70°. The necessity for this limit is obvious, as there would be a risk of premature explosion due to rocking of the mine by wave and like surging movements. The ship depicted in Fig. 16 has struck a mine moored at a depth, *d*, and has drawn it under the bottom. In the position shown the angle of tilt is that at which the mercury seal comes into operation.

Electro-mechanical mines have been found to be the most useful of all, as they can be dropped overboard from any vessel or launched from a torpedo-tube, and then left, for the electric battery is contained in the mine itself. Desirable from every point of view, and yet not always acted upon, is the practice of fitting them with automatic devices, such as clockwork, whereby they are rendered ineffective after a given interval of time. Even if discrimination is used in laying such mines, nothing can prevent a storm from scattering them broadcast into the track of merchant vessels, so that this safety device should always be fitted. Equally desirable, and in this case always practised, is the fitting of a time control for rendering the mine effective. The mine-layer certainly wants to feel that he has time to get out of the district before any harm can possibly happen. Usually the control comprises a layer of solid sugar between two adjacent parts

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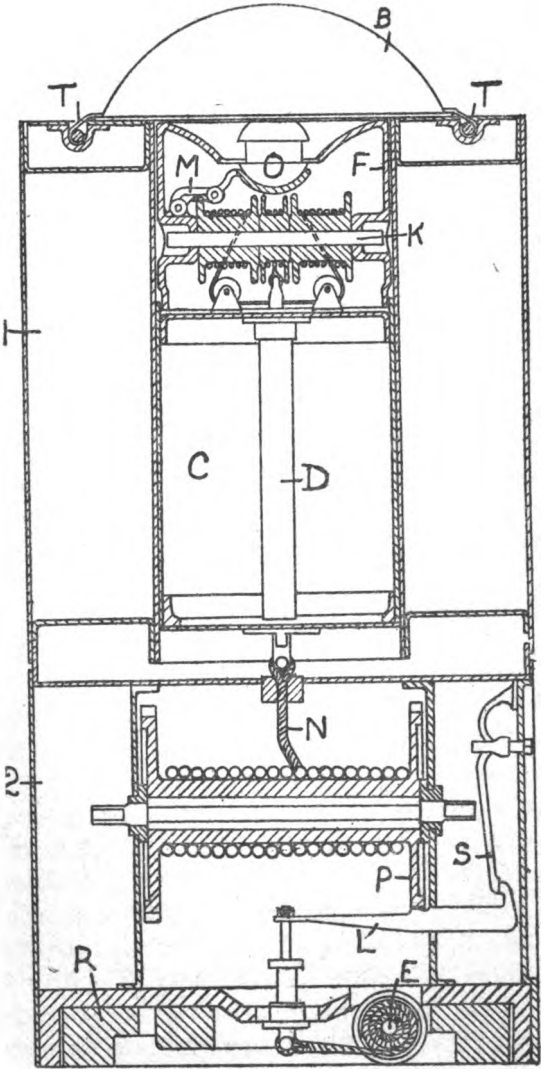

FIG. 17.

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of the circuit wire, these two parts coming into contact when the sugar dissolves in the water.

Messrs. Vickers, Ltd., are making a mine which was described with detailed drawings in Brassey's *Naval Annual*, the features of which are—(1) A trip mechanism which acts on the detonator by percussion and not electrically; and (2) a simple device for maintaining the depth of submergence of the buoy. Fig. 17 shows the essential features of this mine.

The complete automatic mine includes the containing cylinder, the explosion chamber, the firing mechanism, the actuation mechanism, the float, the anchor, the automatic adjustment between the mine and the anchor, the plummet, and the series cable.

The container, *I*, is made as an annular float member, within which is placed the container, *C*, for the charge. A detonator tube, *D*, passes down the centre.

The mechanism for firing the mine is as follows: A ball, *O*, rests in a socket at the end of a lever, *M*, which forms a stop for two drums. A cable connects the ball, *B*, to the lever. Upon the outer part of the drums there are rolled respectively two cables, the ends of which are attached to the explosive chamber, *C*. Upon an intermediate drum, *K*, is coiled a cable, serving to pull the striker of the detonator, *D*. This cable is in practice about 60 centimetres shorter than the other two cables. A frame, *F*, concentric with the container, *C*, carries all the above mechanism. Under the action of the violent shock imparted to the mine by the impact of a vessel, the ball, *O*, is thrown out of its socket, and the weight of this ball dragging upon the connecting cable withdraws the

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lever, *M*, from the drum, *K*. Being set free, the cables unroll, and the mine, no longer held up, descends in the water by its own weight, and in addition is pulled downwards by the anchoring cable, *N*. At the same time, the cylinder, *I*, which enclosed the explosion chamber, commences its ascent under the influence of its own buoyancy, which has for result the simultaneous unrolling of the three cables from the drum, *K*. The middle cable, being shorter than the two others, will first unroll itself completely, and will then pull on the rod of the striker, compressing the spring, which engages the end of a guiding casing formed in one with the striking-pin. As soon as the tractive effort on a transverse pin exceeds the breaking limit the pin will break, and the striker will be violently projected against the detonating cap.

When the mine is sunk to a suitable depth, and after a few minutes, the two seals, *T*, will have dissolved, and the rising of the float, *B*, pulls on a cable, and moves out of the way a cup, passing underneath the holder in which the ball, *O*, rests. In this position the mine is in an active condition, the ball, *O*, being ready to escape from its holder at the first shock of a hostile ship.

The anchor, *Q*, is composed of a sheet-iron cylinder, and is of such a shape that on connecting it to the mine enclosing cylinder there is formed a kind of barrel, which can be easily rolled for convenience of handling on the ship and for putting it in the water. This cylinder has a weighted bottom to increase its stability, and contains the mechanism of the anchor. The wheel, *P*, has coiled upon it the anchoring cable,

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N, of the mine. In the normal condition the cable wheel is held fast by a lever, *L*, which engages the teeth of the notched edge of the wheels, *P*. The lever is pressed against this rack by the spring, *S*. An annular weight, *R*, serves not only to weight the anchor, but to act as a lock upon three bars when the mine is vertical, which bars serve to disengage the hooks holding the anchor to the mine-bearing cylinder. The descent of the weight, *R*, is just sufficient to

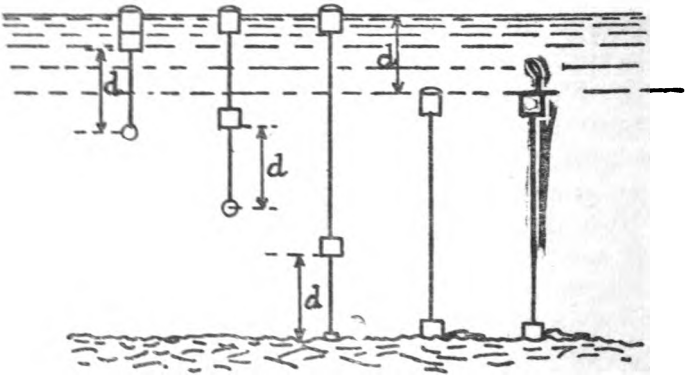

FIG. 18.

release the hooks, and set free the anchor, *A*. This weight is locked during transport.

A plummet, *E*, is attached to one end of a rope, the other end being coupled to the lever, *L*. The operation takes place as shown diagrammatically in Fig. 18. When placed in the water, the entire apparatus, consisting of the anchor and the mine-holder united, assumes the vertical position because its centre of gravity is sufficiently low; and, as shown at the ex-

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treme left of the diagram, the mine-holder is at the surface, the attached anchor below the mine, and the plummet hanging a distance, *d*, below the anchor.

In the next position, the ring, *R* (Fig. 17), has released the hooks, and the anchor has been separated from the mine-holder, which remains at the surface. The barrel unwinds its cable, and the anchor descends towards the bottom, because the plummet, which descends with it, draws down the lever and holds the rack disengaged. When the plummet touches the bottom of the sea, the lever, *L*, upon which the weight of the plummet no longer acts, is drawn up by the spring, *S*, and again clasps the ratchet wheel, *P*. The cable which unites the mine to the anchor no longer unrolls, the mine remaining at the surface. The anchor then fills with water, sinks, and pulls down the mine-holder to a depth, *d*. The depth of immersion of the mine-holder is therefore automatically decided by the length of the cable of the plummet, whatever be the depth of the water.

The two seals, *T*, having dissolved in the water, the float, *B*, becomes detached from the mine by its buoyancy, and puts the firing apparatus of the mine in the position of action, as shown at the extreme right of the diagram.

Messrs. Beardmores, Ltd., have the manufacturing rights of the Leon Mine, which has no anchoring chains, and is cylindrical, and of such a diameter that it can be launched from a torpedo-tube. This buoy is non-floatative, and, when put into the water, sinks. It is provided with a screw, which is set into operation as soon as a given depth is exceeded, and so brought

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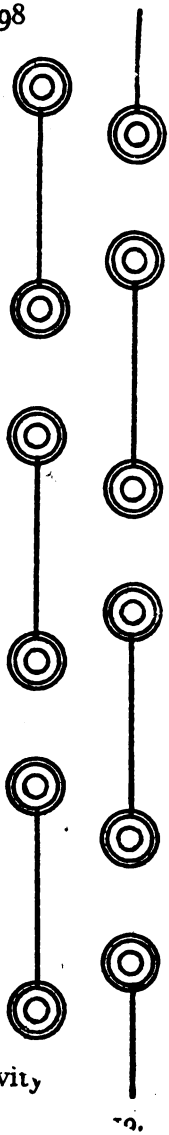

Fig. 19.

until the proper level is reached again, when the screw is put out of action. In practice, the mine oscillates up and down on either side of the mean position for which it is set.

A collection of mines laid in a given area of the sea is known as a "mine-field." Sometimes the mooring-cables are coupled, so that even if a ship would have otherwise missed a mine, yet by running into the coupling cross-cable it draws one up against its sides. Such an arrangement is illustrated in Fig. 19, in which alternate couples of mines in any one row are coupled, and the rows are staggered. Although a boat may enter the mine-field and miss the first row, yet because of this disposition of the mines it is bound to come up against a mine or coupling-rope in the second row.

Countermining and other Means for Removing Mines.—When it is desired to move through a mine-field, small mine-layers are sent to lay other mines of the type exploded positively by the making of electric contacts. In this manner the enemy mines are exploded by the concussion, and a clear path is opened up. This is known as "countermining."

The countermines are usually laid in

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rows, with three or four buoys along the line to indicate a clear waterway. At night the buoys would be provided with lights. The mine-layer is usually fitted with spars, to which the mines and buoys are attached, all being coupled in succession by the mooring and electric cables. The first mine having been dropped, the mine-laying boat gets under way, and the buoys and mines are unslipped in turn as the cable tightens up between the one unit last dropped and the one to be dropped next.

The concussive waves produced by the exploding countermines really acts upon the shell or container of the mines, and by causing it to break either the circuit is completed and the mine destroyed by explosion, or else the water leaks in and sinks the mine. After the explosion of the countermines, a steel cable is towed across the field with a view to clearing anything which may have remained.

The use of a cable and netting in tow of two or more trawlers is being extensively adopted for deep-sea mine fields at the present time, and presumably with good effect, for the fleet of boats so engaged has been considerably and consistently enlarged in numbers.

The question of submarine mining involves many difficult problems, both for the naval men and the diplomatists of the country proposing to indulge in this practice. It would appear that in discussing alternative plans of attack or defence the naval man must first consider where to place mines so as to be most effective for his purpose. Having decided, it is then the duty of the statesmen to decide whether any information should be given to neutral countries

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or the world at large. There is absolutely no doubt that, if the country at war is in a bad way, it will only consider itself, and not neutrals. On the other hand, if the country has the whip-hand of its opponent, and feels it can afford to let neutrals know of its mine-fields, it should do so on the ground of humanity, and for other reasons, mainly selfish, but nevertheless important.

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CHAPTER X

AUXILIARY VESSELS

EACH group or flotilla of submarines is provided with a parent ship or depot, which operates from the port or base to which the flotilla is attached.

These ships are fitted with plant for charging accumulators, and for storing and producing compressed air, and also with the necessary " leads " and pipes for conveying the supplies to submarines lying alongside. Full stores of torpedoes and oil fuel are maintained on board, for which also transhipping facilities are provided. Diving apparatus is carried, and skilled divers are numbered among the boat's crew. In addition to this, these boats have the very latest wireless telegraphic and telephonic apparatus, which enables them readily to pick up messages demanding their attention.

The most important of the whole equipment is the workshop. Every possible side of the engineering trade is represented in miniature: lathes, drilling machines, slotting and milling machines, small-gear cutters, punching machines, forges and blacksmith appliances, furnaces for melting down white metals, coppersmith's outfit—indeed, everything that is useful for effecting repairs to any piece of mechanism likely to break

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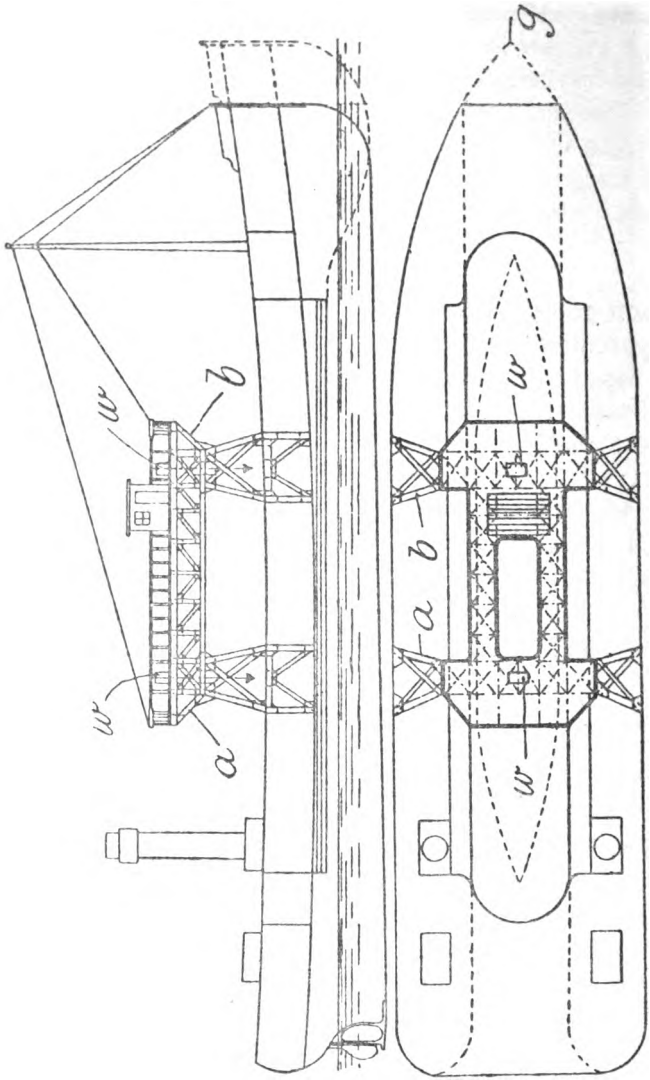

FIG. 20.

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down. All the bother of going into dockyard hands for repairs is thus avoided, valuable time is saved, and no one's temper is affected.

One such depot ship, the *Maidstone*, built by Scotts, is 320 feet long, 45 feet beam, and of 3,600 tons displacement. A speed of 14 knots can be obtained from her. Similar vessels—the *Adamant* and *Alecto*—are

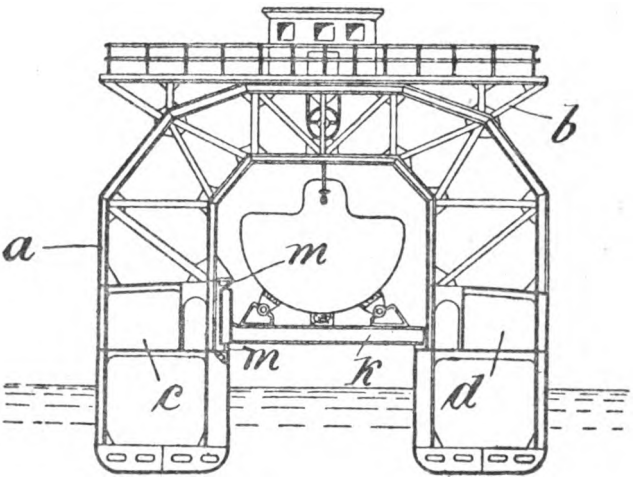

FIG. 21.

building by Cammell Lairds. These are ships specially designed for the service, and are intended particularly for those bases, such as Harwich, which have no other official naval facilities for repairs.

At the main naval stations, the parent ships are old cruisers turned over for this service, and they do not really act as depot ships. The workshop and other facilities are limited, but some amount of transforma-

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tion in the boats has been made, which better adapts them for their new duties.

The submarines attached to the Mediterranean, Australian, and China Stations, and those stationed at Gibraltar and Halifax, use the ordinary naval service for repairs and stores.

Salvage Boats.—When the A 1 was lost, and when subsequent disasters occurred, it was found to be a very difficult task to raise the sunken submarines, and in one case at least the work was entirely unsuccessful, and the operations had to be abandoned.

The salvage boats owned by firms specializing in the recovery of wrecked and sunken vessels were chartered, but their fittings were not of the right kind for this new work.

The Admiralty now have a salvage vessel of their own, which Vickers built. It is 160 feet long, and 44 feet wide, and there are ten tubes extending downwardly to the bottom through which special lifting cables are intended to pass. The requisite steam capstans and lifting gear are situated on the deck.

The cables are secured to, or fastened around, the sunken submarine by divers, and when it is raised it is supported in a recess in the bottom of the boat. To support the additional weight of the lifted vessel, special tanks are emptied of water, and so give the extra floatative power desired. These tanks are filled with fresh water for supplying the flotilla, so that the boat also acts as a depot or supply ship. In the Vickers boat the capacity of the tanks is 1,000 tons.

A floating dock has been stationed at Portsmouth,

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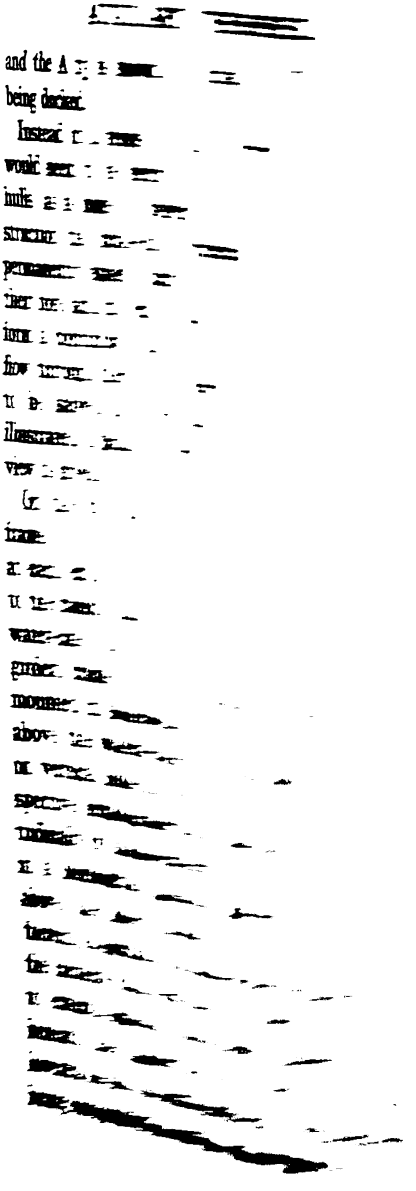

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The salvage boats owned by firms specializing in the recovery of wrecked and sunken vessels were chartered, but their fittings were not of the right kind for this new work.

The Admiralty now have a salvage vessel of their own, which Vickers built. It is 160 feet long, and 44 feet wide, and there are ten tubes extending downwardly to the bottom through which special lifting cables are intended to pass. The requisite steam capstans and lifting gear are situated on the deck.

The cables are secured to, or fastened around, the sunken submarine by divers, and when it is raised it is supported in a recess in the bottom of the boat. To support the additional weight of the lifted vessel, special tanks are emptied of water, and so give the extra floatative power desired. These tanks are filled with fresh water for supplying the flotilla, so that the boat also acts as a depot or supply ship. In the Vickers boat the capacity of the tanks is 1,000 tons.

A floating dock has been stationed at Portsmouth,

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and the A 13 is shown in Plate XVI. in the act of being docked.

Instead of a recess in the bottom of the boat, it would seem to be better to form the ship with twin hulls, as is done in foreign navies. In such a construction the dock-ship comprises two parallel hulls permanently spaced apart, and connected together at their fore and aft ends above the water-line, so as to form a continuous structure, the water being able to flow through the space between the hulls. The boat to be salved can be drawn up into this space, as illustrated in plan and elevation in Fig. 20. A sectional view is given in Fig. 21.

On the two hulls is arranged a rigid supporting frame, *a*, *b*, which is provided with raising tackle, *w*, at each end, so that the boat, after being connected to the raising tackle, can be raised thereby above the water-line. The two hulls are provided with cross-girders, frames, or the like boat carriers, *k*, which are mounted in slideways on the hulls, or are mounted above the water-line at the inner sides of the hulls on vertical hinges, as at *m*. According to these respective arrangements, the carriers can be slid longitudinally or transversely of the hulls, or can be turned in a horizontal plane parallel with, and against or above, the inner sides of the hulls or into recesses therein, to permit of the boat being raised, after which the carriers can be slid or turned into position so as to extend across the space between the hulls and beneath the raised boat, when the latter can be lowered so as to rest firmly on the carriers while still being suspended from the raising tackle.

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After the desired repairs are effected, the boat may be lowered into the water, and can pass out of the dock-ship at either end. The decks of the two hulls are provided with workshop structures, *c*, *d*, which are arranged on the outer sides of the hulls, so as to leave broad gangways on the inner sides of the hulls for facilitating working operations, and so as to serve as a protection against waves. The workshops are preferably built in, and so as to strengthen the legs of said supporting frame.

By properly recognizing the limitations of submarines, and providing a good fleet of auxiliary vessels of the salvage and depot ship type, the efficiency of each submarine, and of the whole number comprising a flotilla, can be greatly enhanced.

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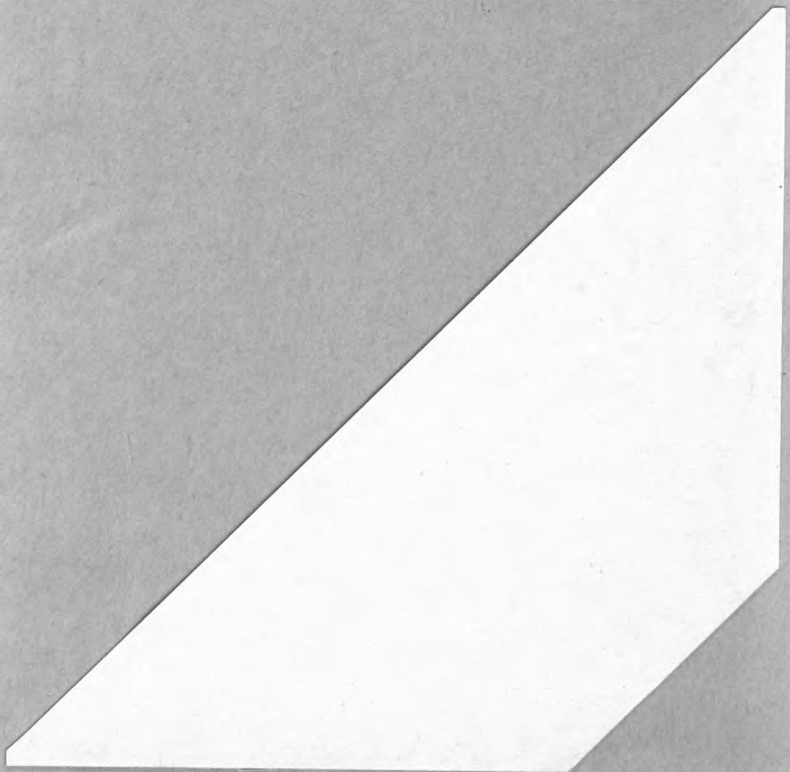

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